SURGE ARRESTER MODELLING USING ALTERNATIVE TRANSIENT PROGRAM

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Abstract: This paper deals with surge arrester modelling in EMTP ATP software. Two commonly used models are presented – Pinceti and Fernandez-Diaz model. In this text, the procedure of model parameters calculation is also described. Both models are then tested using a current impulse of different wave shape and amplitude and the residual voltages obtained from the simulation are compared to the data from the surge arrester manufacturer.

Keywords: surge arrester, Pinceti model, Fernandez-Diaz model, EMTP ATP

1 INTRODUCTION

In the electrical power network, voltage higher than the nominal value can pose a thread for insulation of electric devices. To avoid problems caused by overvoltages, the surge arresters are installed. The exterior distribution networks are protected by either the Metal-Oxide Surge Arrester (MOSA), that uses zinc-oxide semiconductor as a resistor, or gapped type with Silicone-Carbide (SiC) resistors.

The main features of MOSA are its extremely non-linear V-I characteristics, small power loss, high energy absorbing capability, simple design, good reliability and long lifetime. When studying switching overvoltages, it is sufficient to represent the surge arrester by the V-I characteristics. For lightning studies, however, more sophisticated model that considers the surge arrester´s dynamic characteristics had to be developed.

The design of frequency-dependent surge arrester model was proposed by IEEE Working Group 3.4.11 [1]. This model basically comprises non-linear resistors *A0* and *A1* separated by RL low pass filter. The parameters of the individual components are calculated using the data of the arrester physical arrangement. The IEEE model is shown in Figure 1. IEEE model became the foundation for further surge arrester model development. In this paper, Pinceti and Fernandez-Diaz models, both based on IEEE model, are deeper discussed.

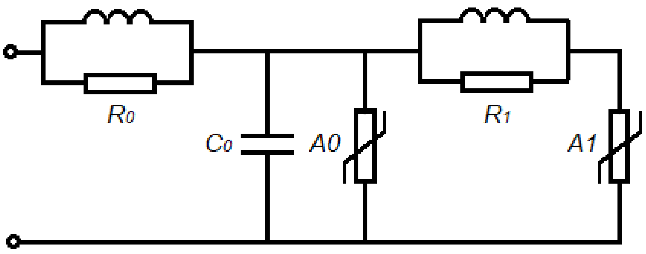

Figure 1: IEEE surge arrester model

In the Pinceti model [2], the capacitance is eliminated and the parallel resistances are replaced by one resistance R (circa 1 MΩ) to avoid numerical problems. The Fernandez-Diaz model [3] also includes the non-linear-resistors *A0* and *A1*. In this case, these elements are connected by inductance. The general description and parameters calculation of these two models are described in following text.

2 MODEL PARAMETERS CALCULATION

In this paper, the model parameters are calculated for the MWK 14 surge arrester from ABB, whose technical data are available in [4]. The basic data needed for the calculation are listed in Table 1.

Rated voltage V_r	Residual voltage $V_{r1/T2}$ at 10 kA$_{\text{peak}}$ steep current impulse wave 1/T_2 µs	Residual voltage $V_{r8/20}$ at 10 kA$_{\text{peak}}$ steep current impulse wave 8/20 µs
17,5 kV	50,7 kV	43,0 kV

Table 1: Nominal MWK 14 surge arrester parameters

2.1 PINCETI MODEL

As mentioned above, Pinceti model shown in Figure 2 is based on IEEE model modification. The non-linear resistors are defined using curves in Figure 3 proposed by IEEE Working Group 3.4.11. Voltage on the vertical axis is in proportional units referred to the peak value of the residual voltage $V_{r8/20}$ at 10 kA$_{\text{peak}}$ steep current impulse wave 8/20 µs.

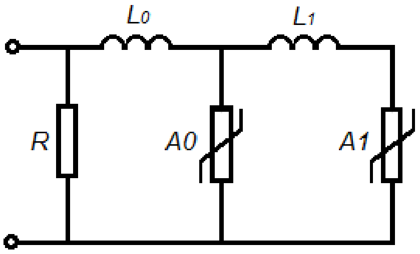

Figure 2: *Pinceti surge arrester model*

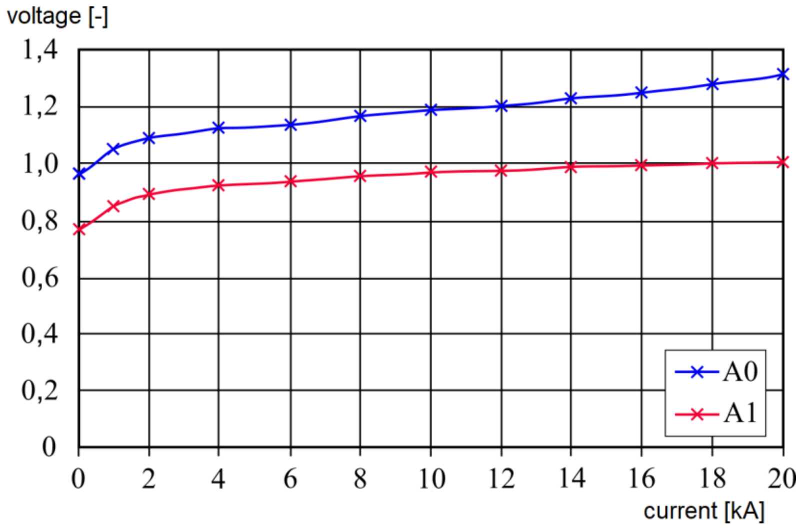

Figure 3: V-I characteristics of the non-linear resistors A0 and A1 [5]

Inductances L_1 and L_0 (values in µH for inductance and kV for voltage) are defined as:

$$L_1 = \frac{1}{4} \cdot \frac{V_{r1/T_2} - V_{r8/20}}{V_{r8/20}} \cdot V_r \tag{1}$$

$$L_0 = \frac{1}{12} \cdot \frac{V_{r1/T_2} - V_{r8/20}}{V_{r8/20}} \cdot V_r \tag{2}$$

This calculation requires no information about the surge arrester physical arrangement. The resistance in the diagram is R = 1 MΩ. Using equations (1) and (2) and the MWK 14 surge arrester technical data, the values of the inductances can be determined.

$$L_1 = \frac{1}{4} \cdot \frac{V_{r1/T_2} - V_{r8/20}}{V_{r8/20}} \cdot V_r = \frac{1}{4} \cdot \frac{50{,}7 - 43{,}0}{43{,}0} \cdot 17{,}5\ \mu\text{H} = 0{,}783\ \mu\text{H}$$

$$L_0 = \frac{1}{12} \cdot \frac{V_{r1/T_2} - V_{r8/20}}{V_{r8/20}} \cdot V_r = \frac{1}{12} \cdot \frac{50{,}7 - 43{,}0}{43{,}0} \cdot 17{,}5\ \mu\text{H} = 0{,}261\ \mu\text{H}$$

2.2 FERNANDEZ-DIAZ MODEL

This model also uses no data about the physical arrangement of the arrester. The diagram of Fernandez-Diaz model is in Figure 4.

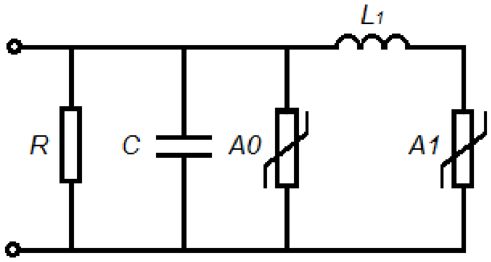

Figure 4: Fernandez-Diaz model

The non-linear resistors *A0* and *A1* are the same as for the Pinceti model (see Figure 3) and the resistance is also 1 MΩ. Inductance L_1 a capacitance C are calculated as follows (inductance in µH, capacitance in pF and voltage in kV):

$$L_1 = \frac{2}{5} \cdot \frac{V_{r8/20} - V_{SS}}{V_{r8/20}} \cdot V_r \tag{3}$$

$$C = \frac{1}{55} \cdot \frac{V_{r8/20} - V_{SS}}{V_{r8/20}} \cdot V_r \tag{4}$$

In (3) and (4), the V_{SS} is the residual voltage at 500 A current surge wave 60/2000 µs or 30/70 µs. For the MWK 14 surge arrester, this value is V_{SS} = 34,5 kV. Knowing the data needed, the values of inductance L_1 and capacitance C can be calculated.

$$L_1 = \frac{2}{5} \cdot \frac{V_{r8/20} - V_{SS}}{V_{r8/20}} \cdot V_r = \frac{2}{5} \cdot \frac{43{,}0 - 34{,}5}{43{,}0} \cdot 17{,}5\ \mu\text{H} = 1{,}384\ \mu\text{H}$$

$$C = \frac{1}{55} \cdot \frac{V_{r8/20} - V_{SS}}{V_{r8/20}} \cdot V_r = \frac{1}{55} \cdot \frac{43{,}0 - 34{,}5}{43{,}0} \cdot 17{,}5\ \text{pF} = 0{,}0629\ \text{pF}$$

3 SIMULATION RESULTS

The models presented in this paper are verified using EMTP ATP software. A series of simulations was performed to compare residual voltages from the manufacturer catalog and the residual voltages obtained from the performed simulations. Residual voltage is a peak value of voltage between surge arrester terminals during the passage of discharge current and it is one of the most important surge arrester parameters. In arrester datasheets, the residual voltages for different wave forms and amplitudes of the discharge current can be found.

As for the simulation, the model of surge arrester was created in EMTP ATP and then tested using a current source with two different wave forms – 8/20 µs wave shape with 10 kA peak and 1/T2 µs wave shape with 1 kA peak. The current impulse was modelled with Heidler type source [6].

The response of the surge arrester models to these current impulses are displayed in Figure 5. On the vertical axis, there is voltage measured at the surge arrester input. The peak value of this voltage determines the residual voltage at the considered current impulse.

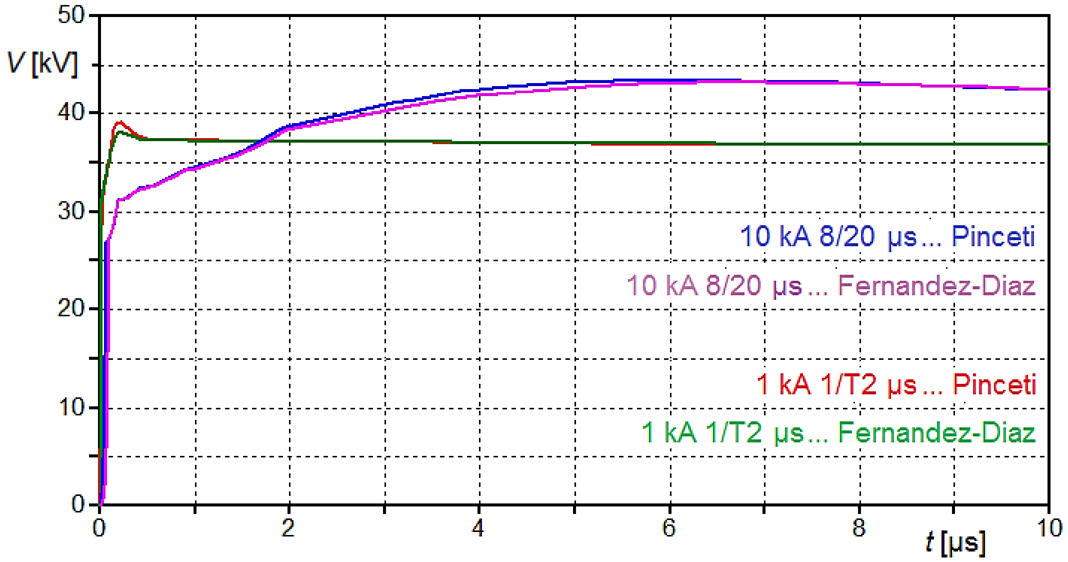

Figure 5: Residual voltages at different current impulses

Table 2 shows the final comparison of residual voltages given by manufacturer and residual voltages obtained from the simulations. It can be seen, that both surge arrester models work well and therefore can be used for further simulations.

Residual voltage		1 kA peak, 1/T2 µs wave shape	10 kA peak, 8/20 µs wave shape
From manufacturer catalog [4]		**36,7 kV**	**43,0 kV**
Pinceti	From simulation	39,1 kV	43,5 kV
	Relative error	6,5 %	1,2 %
Fernandez-Diaz	From simulation	38,2 kV	43,3 kV
	Relative error	4,1 %	0,7 %

Table 2: Residual voltage comparison

4 CONLUSION

In this work, the MWK 14 surge arrester was modelled in EMTP ATP using two different models. From the result it is obvious, that both Pinceti and Fernandez-Diaz model can be applied in simulations of overvoltage studies, although the Fernandez-Diaz model had smaller difference from the manufacturer data than the Pinceti model.

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