Surge Arrester Models Analysis using EMTP-RV Software

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ABSTRACT

Lightning is one of the major sources of transient overvoltage in transmission system. This can damage overhead lines and other apparatus's of transmission system and also dangerous for human life's. To overcome the effect of transient over voltage, surge arresters are used. To protect power system against lightning stokes and switching surge, surge arresters are used. For this study, a surge arrester model and transmission line system are developed using restructured version of electromagnetic transient program (EMTP-RV). Surge arrester is connected between phase and earth and diverts the surge current to earth without affecting the supply. This paper examines the different surge arrester models and comparing their results. All these modeling and calculation were done in EMTP-RV program.

Keywords: Lightning stroke, Surge Arrester, Transient over voltages, Modeling, EMTP-RV , Electromagnetic transients, Parameter estimation.

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I. INTRODUCTION

Overvoltage transient is the major source of disturbance in transmission system. This is due to switching operations in nearby circuit breaker or also due to lightning stokes. Lightning phenomenon in overhead transmission line cause savior disturbance and damage the equipment. For lightning performance, modeling of transmission line with lightning surge is very important. The study of lightning carried out in two ways, one is the use of suitable software for lightning phenomenon analysis and solution to improve it. Second is the cost of installation, maintenance and service to protect against lightning also called technical and economic study of the phenomenon.

To protect power systems against lightning stoke and switching surge, surge arresters are used. There are many line surge arrester applications, such as: line lightning performance improvement, extended protection of substations, switching surge control, compact lines, line voltage uprating, touch and step voltage reduction, etc.

In this paper, different surge arrester models are simulated using EMTP-RV and results are compared. Also validation of surge arrester is done using this software and getting scope view of the plot.

II. METHODOLOGY

Basically, methods/steps essential for successful completion of the dissertation is known as methodology. Software used and method used for the completion of paper is explained in this chapter.

Surge arrester model is selected to fulfill the requirement of surge arrester. Several papers on surge arrester are compared and the difficulties in modeling of surge arrester is comparing of model parameter with manufacturer data and specifications.

a. IEEE Model

"The IEEE model is a model which contains two elements A1 and Ao of nonlinear in character which is projected by IEEE working group 3.4.11 as represented by figure 2. In this model they connect a resister 'R1' and inductor L1 in parallel across nonlinear element A1 and a capacitor 'Co' is also connected which is linked with the elevation of surge arrester. Here, a resistor Ro and inductor Lo is also connected in parallel which enrich the stability of the system.

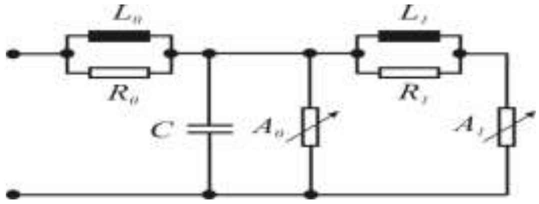

Figure2 IEEE model

These elements are computed from:

$$R_0 = 100 \cdot \frac{d}{n} [\Omega]. \quad (1)$$

$$L_0 = 0.2 \cdot \frac{d}{n} [\mu H]. \quad (2)$$

$$R_1 = 65 \cdot \frac{d}{n} [\Omega]. \quad (3)$$

$$L_1 = 15 \cdot \frac{d}{n} [\mu H]. \quad (4)$$

$$C = 100 \cdot \frac{n}{d} [pF]. \quad (5)$$

Where; n represents the number of disk connected in parallel and length of surge arrester is represented by d in metre" [5].

"Equations (1-5) is used to calculate different elements of IEEE model. The characteristics curve of nonlinear elements is represented in figure 3" [10]. Now, this model is simulated in EMTP-RV with the help of their library (Fig. 4)

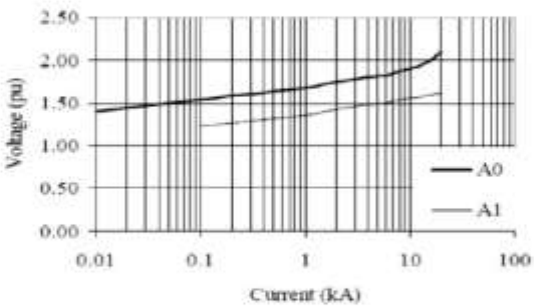

Figure3 Nonlinear V-I characteristic for $A0$ and $A1$

I (kA)	V (per unit) A_0	V (per unit) A_1
0.01	0.798	-
0.1	0.889	0.770
1	1.050	0.850
2	1.077	0.889
4	1.119	0.919
6	1.138	0.938
8	1.169	0.956
10	1.188	0.969
12	1.206	0.975
14	1.231	0.988
16	1.250	0.994
18	1.281	1.000
20	1.313	1.006

Table 1: (I-V) value of nonlinear elements A1 and A0

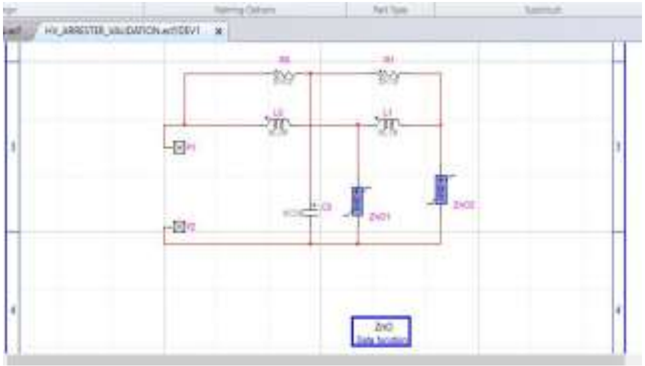

Figure4 Simulation of IEEE model in EMTP – RV

b. The PINCETI Model

This model is much identical with the model proposed by IEEE working group, however couple of changes were done in this model. The change is that here we don't use filter circuit of inductor and resistor in parallel instead of that only use inductor for both nonlinear elements and also there is no capacitor in between them as represented by figure 5.

" Inductances $L1$ and $L0$ calculation is done by using equation (6,7).

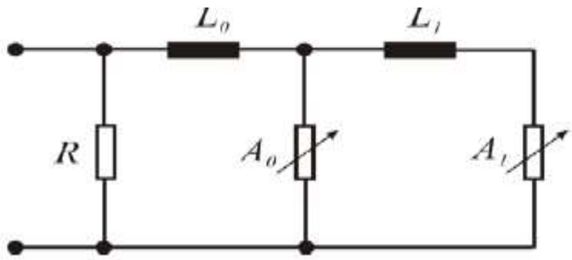

Figure 5 Pinceti Model

$$L_0 = \frac{1}{12} \cdot \frac{U_{r1/T_2} - U_{r8/20}}{U_{r8/20}} \cdot U_r. \quad (6)$$

$$L_1 = \frac{1}{4} \cdot \frac{U_{r1/T_2} - U_{r8/20}}{U_{r8/20}} \cdot U_r. \quad (7)$$

Where, U_{r1}/T_2 and $U_{r8}/20$ are the residual voltages at their shapes of current surges at 10 kA and here we assume 1 M ohm resistance" [6]. Now, this model is simulated in EMTP-RV with the help of their library (Fig. 6)

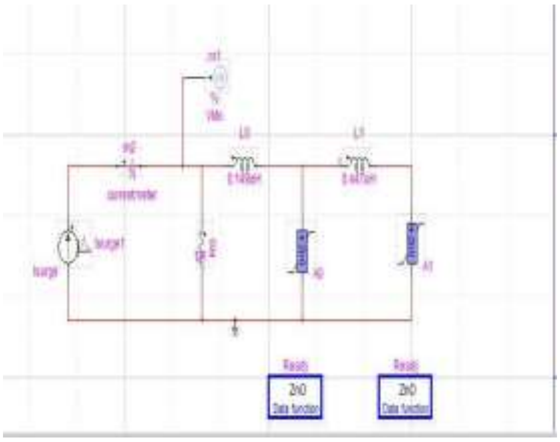

Figure 6 Simulation of Pinceti model in EMTP – RV

III. Zinc-Oxide Surge Arrester Validation Result

Generally, the modeling of this metal oxide arresters are modeled with the help of ZnO arrester which is available in EMTP-RV software library. All the parameters from equation 1 to 5 are used in ZnO arrester as shown in fig 4. The surge current source is connected with ZnO surge arrester to get voltage and current graph.
After running the simulation, the plot of surge current and generated voltage are obtained as shown in figure 14.

Fig 13. ZnO surge arrester energization.

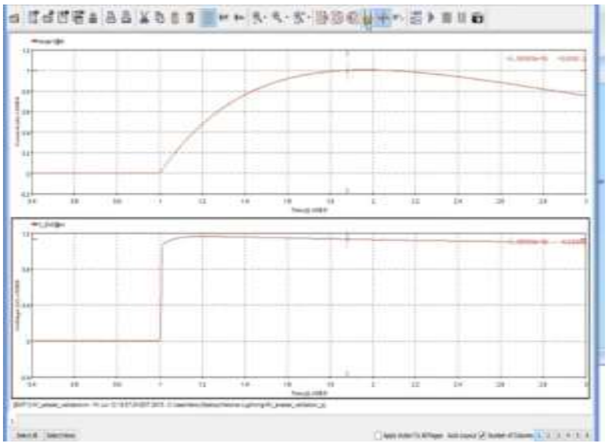

Figure 14 Scope view of surge current and voltage generated

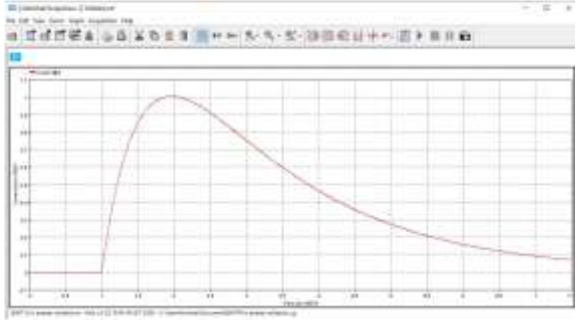

Figure 15 Scope view of surge current

IV. PARAMETERS SELECTION AND COMPARISION OF SURGE ARRESTER MODELS

“Here we choose manufacturer data for the calculation of different parameters in surge arresters. With the help of residual voltages and putting the value of ‘n’ and ‘d’ in above equations (1-7), we can calculate the parameters of surge arresters.
Surge arrester data from manufacturer with Vr = 10 KV and d=0.187 m is represented by Table 2

Wave	1/5 µs		
I [kA]	1	5	10
V [kV]	21	25.6	29
Wave	8/20 µs		
I [kA]	1	5	10
V [kV]	20.8	23.2	24.6
Wave	30/60 µs		
I [kA]	0.125	0.5	1
V [kV]	24.6	19.7	20.5

Table 2 Surge arrester data from manufacturer”[9].

After putting all values from above table in equations 1 to 5 we calculate: R0 = 20.1 Ω, L0 = 0.041 µH, R1 = 11.295Ω, L1 = 3.01 µH and C = 520 pF. for IEEE model at given surge current shape .
And we get L0 = 0.1509 µH and L1 = 0.4971µH after putting all data in equations 6 and 7for Pinceti model. All these parameters is table 3.

Table – 3 Parameter calculation table

Model	$L0\ (\mu H)$	$L1\ (\mu H)$	$R0\ (\Omega)$	$R1\ (\Omega)$	C (pF)
IEEE	0.041	3.01	20.1	11.295	520
Pinceti	0.1509	0.4971	100000	-	-

Now, these two models were simulated in EMTP-RV software by adding a surge current device to change the value of surge current wave from manufacturer datasheet as represented in table2 to get respective voltage through voltage scope and values are given in table 4.
From table 4 relative voltages through simulation is compared with manufacturer's voltage as in table 2. Equation 8 gives formula to calculate error in both model as shown in table 4.

$$Error(e) = \frac{V_{r\,simulation} - V_{r\,manufacturer}}{V_{r\,manufacturer}} \times 100\ \% \quad (8)$$

Where; $Vr\ simulation$ and $Vr\ manufacturer$ are the residual voltage due to simulation and from manufacturer data.

Table 4 Simulation voltages and error calculation of different surge arrester.

Wave	1/5 µs		
I [kA]	1	5	10
V [kV] IEEE	21.6098	26.0781	27.6525
Error(%) IEEE	2.90	1.87	- 4.65
V [kV] Pinceti	21.495	25.6742	28.42
Error(%) Pinceti	2.36	0.29	2.00
Wave	8/20 µs		
V [kV] IEEE	20.5591	23.129	24.5991
Error(%) IEEE	-1.16	-0.31	0.00
V [kV] Pinceti	20.9794	23.2907	24.4913
Error(%) Pinceti	0.86	0.39	- 0.44
Wave	30/60 µs		
I [kA] IEEE	0.125	0.5	1
V [kV] IEEE	18.647	19.8207	20.447
Error(%) IEEE	3.02	0.61	- 0.26
V [kV] Pinceti	19.1005	20.2946	20.9252
Error(%) Pinceti	5.53	3.02	2.07

Both IEEE and Pinceti models were matched with maker's table in EMTP-RV software. For three different wave shapes, IEEE gives better result as Pinceti model in all aspects

V. CONCLUSION

A detailed discussion relating to surge arrester and related issues was presented, and a detailed simulation study was performed to determine peak surge levels. The objective of the paper is to analyze different surge arrester models as discussed in different papers and do simulation of the models in EMTP-RV program. Then relate these models with data provided by manufacturer and relative errors are calculated. From the results shows that IEEE model proposed by IEEE working group is suitable for all types of surge current shapes.

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