The relationship between operating maintenance and lightning overvoltage in distribution networks based on PSCAD/EMTDC

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Abstract. The model of lighting direct strokes on 10 kV distribution line in Guangzhou was built and the transient procedure was considered based on the software of PSCAD/ECTDC. The effect of arrest and ground resistance operating maintenance on lightning overvoltage in distribution networks has been discussed. The results show that operating maintenance of arrest has significant suppression on lightning overvoltage. In addition, the ground resistance of tower has little influence on the lightning overvoltage.

Introduction

Electric power distribution system constitute the greatest risk to the interruption of power supply. However, power supply in distribution system draws less attention than that in generation and transmission system before. Recently, with the development of economy, especially high-technology, distribution network, an important component of power system has drawn more and more attention. Lightning overvoltage is the major cause of line insulation flashovers in distribution system. Therefore, there are a large number of researches on experimental and theoretical calculation by investigating lightning overvoltage on the overvoltage in distribution networks [1-6].

Lightning overvoltage in power system can be divided into four types: (i) direct strokes, (ii) direct strokes to nearby structures, (iii) surge transfer from medium-voltage (MV) to LV voltage lines through distribution transformers, or (iv) induced voltages due to nearby strokes. (i) and (iv) is the main strokes in low distribution power system. Concerning low voltage overhead lines, the main protective measures against short interruptions and voltage sags originated by lightning-induced voltages can be identified as (i) use of surge arresters and/or (ii) use of shielding wires, (iii) increasing of the line insulation level. In this paper, we will focus on (i).

The operating maintenance in power distribution system is of vital important for overvoltage by lightning strokes [7, 8]. Operating maintenance can improve the reliability of electrical equipment. The operating maintenance in distribution system is related to the arrest and ground resistance.

The objective of the present paper is the analysis of the effectiveness of operating maintenance (arrest and ground resistance) on lightning overvoltage in distribution networks for a given 10 kV system. The model of lighting direct strokes on 10 kV distribution line in Guangzhou was built and the transient procedure was considered based on the software of PSCAD/ECTDC.

System modeling

The study was performed using a real 10 kV power system with the configuration shown in Figure 1. The digital simulations were made using PSCAD/EMTDC software. PSCAD was first conceptualized in 1988 and began its long evolution as a tool to generate data files for the EMTDC simulation program. PSCAD (Power Systems CAD) is a powerful and flexible graphical user interface to the world-renowned, EMTDC solution engine. EMTDC is most suitable for simulating the time domain instantaneous responses (also popularly known as electromagnetic transients) of electrical systems [9].

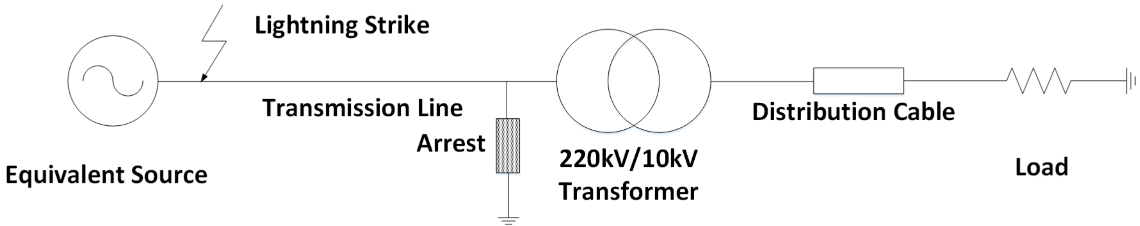

Figure 1 A real 10 kV power system simulated in this study

lightning current model

The waveform of the lightning current is set as standard 2.6/50 μs double-exponential impulse function [10]

$$i(t) = AI_m(e^{-at} - e^{-bt})$$

Where A=1.058, a =15000, b =1860000.

The peak value of waveform is set as 10 kA and the impedance of the lightning channel is 300 Ω. The lightning current in this paper is negative due to the fact that the negative lightning current is more usual than positive. Figure 2 illustrates I-t characteristic curve of arrester.

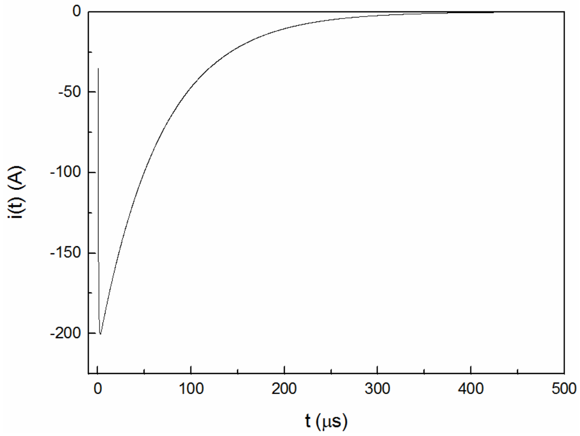

Figure 2 I-t characteristic curve of lightning current

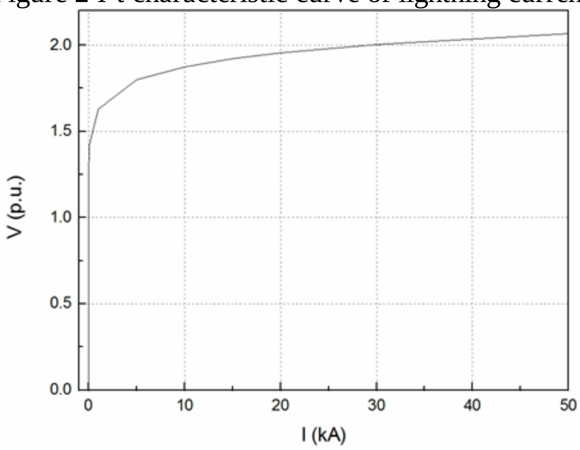

Figure 3 Non-linear V–I characteristic curve of arrester

Surge arrester model

Metal oxide arresters, which present a highly non-linear voltage–current characteristic, are significant for overvoltage coordination studies involving fast front surges. The metal oxide surge arrestor is modeled as a non-linear resistor in series with a variable voltage source. The V–I characteristic of 10 kV rated arrester each nonlinear resistor is illustrated in Figure 3.

Line model

The transmission lines and cables are modeled using one of three distributed (travelling wave) models: Bergeron, frequency dependent (mode), frequency dependent (phase). The most accurate of these is the frequency dependent (Phase) model, which represents all frequency dependent effects of a transmission line, and should be used whenever in doubt. The transmission line was considered to be ideally transposed and the frequency dependence of the longitudinal parameters was modeled. The distribution cable adopts the Bergeron mode. The impedance of distribution cable is 40 Ω.

Transformer model

There are two primary methods by which transformers are modeled in PSCAD: The Classical and the Unified Magnetic Equivalent Circuit (UMEC) methods. In order to analyze the lightning response, transformer modeling for lightning surge analysis considering a capacitance set. The model of transformer considering capacity in Figure 4.

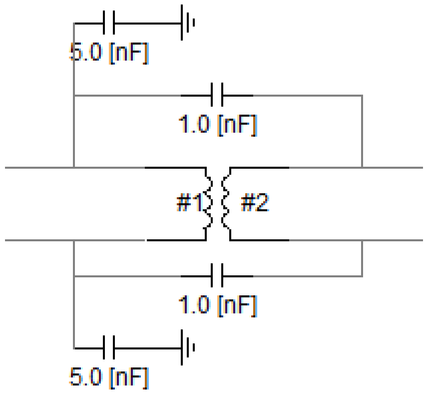

Figure 4 Model of transformer considering capacity

Results and analysis

The relationship between overvoltage and arresters

In this case, the ground resistance of tower is fixed to 5Ω and the lightning current strokes the lightning conductor because the back striking has higher probability than the lightning shielding failure. In addition, the arresters are installed in the high voltage side of transformer.

The position of the lightning current can be divided into near and far from transformer. Figure 5 show the influence of arresters on overvoltage. From the Figure 5a, it can be concluded that the maximum overvoltage (300kV) takes place in the phase B when the lightning strike at far tower with arrest. Although the maximum value also comes from the same phase when the lightning strokes at near tower with arrest (Figure 5b), it decreases more compared with the lightning striking at the far tower. Therefore, the lighting position has a great influence on the lightning overvoltage.

Figure 5c and Figure 5d show that the great overvoltage will occur when the arrests break down. Compare the case including the arrest, the maximum overvoltage originate from phase A. Besides, the overvoltage when the lightning strokes far tower without arrester is smaller than that when the lightning strike near tower, which is contrast with the case including arrest.

In conclusion, the operating maintenance of the arrest is of great importance for the safe operation of power distribution system. Field operator should check up and maintain the arrests regularly.

The relationship between overvoltage and ground resistance of tower

In this case, the arresters are installed in the primary side of transformer and the ground resistance of transformer substation is 2Ω.

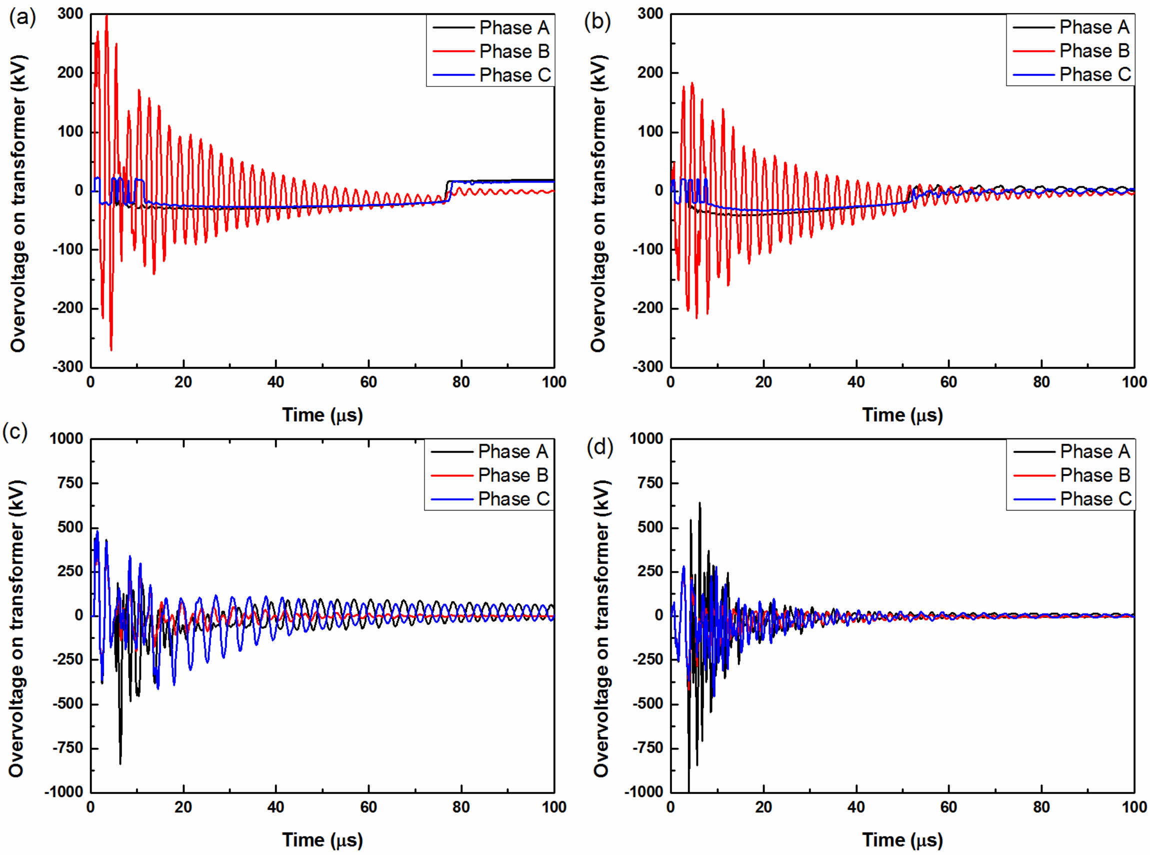

Figure 5 Simulation results of overvoltage. (a) Lightning strokes at far tower with arrest; (a) Lightning strokes at near tower with arrest; (a) Lightning strokes at far tower without arrest; (a) Lightning strokes at near tower without arrest.

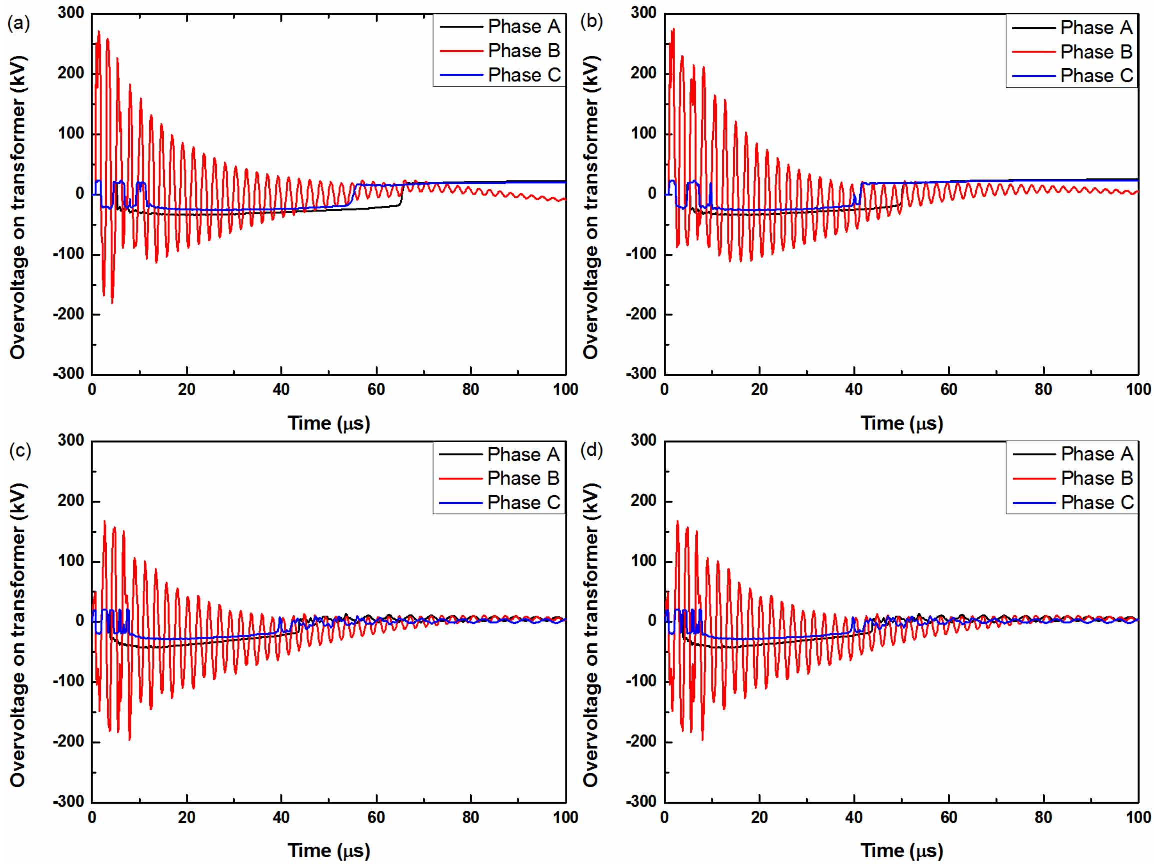

Figure 6 Simulation results of overvoltage. (a) Lightning strokes at far tower with 10 Ω ground resistance; (b) Lightning strokes at far tower with 20 Ω ground resistance; (c) Lightning strokes at near tower with 10 Ω ground resistance; (d) Lightning strokes at near tower with 20 Ω ground resistance.

Figure 6 presents the overvoltage change from the ground resistance of tower. It can be seen that phase B has the maximum overvoltage when the arresters are correctly configured. With the increase of the ground resistance of tower, the overvoltage maintains the same value. In addition, the value goes down when the lightning strokes form far tower to near tower, in accordance with the results shown in 3.1.

Conclusion

In summary, the model of lighting direct strokes on 10 kV distribution line in Guangzhou was built in PSCAD/EMTDC. The results show than operating maintenance of arrest has an important effect on the overvoltage induced by lightning current.

Acknowledgement

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