EVALUATION OF CURRENTS AND CHARGE IN SURGE PROTECTIVE DEVICES IN LOW-VOLTAGE DISTRIBUTION NETWORKS DUE TO DIRECT LIGHTNING STRIKES

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Abstract

This paper presents an evaluation of the values of currents and charges absorbed by surge protective devices (SPDs) connected in low-voltage open-wire overhead distribution networks in the case of direct lightning strikes to primary lines. The calculations have been performed using the ATP (Alternative Transients Program).

The system's components modelling includes the insulation characteristics (voltage versus time to breakdown) of the primary and secondary insulators, a distribution transformer model for high frequencies which takes into account the load conditions.

Several parameters of interest are taken into consideration in the analysis, such as ground resistances of poles and consumers, lightning strike position, front time and crest value of the stroke current; values of the loads components and the secondary line length.

1 INTRODUCTION

The definition of the nominal characteristics of the LV surge protective devices (SPDs) to be used in the networks in order to improve the energy quality, depends on the knowledge of surge amplitudes and the SPD corresponding currents and charges. Among other mechanisms, these surges can be originated from direct strikes in MV lines. They are not very frequent in distribution systems, but their effects are the most severe ones due to their amplitudes. So, simulations were performed with different system topologies in order to obtain these information.

It was considered typical configurations and components of distribution systems.

2 SYSTEM CONFIGURATION

The simulation of distribution systems is particularly difficult due to the variety of configurations and components. Therefore, initially some typical configurations were established for the study. The topologies were studied and one of them was considered representative. In this topology the primary and secondary lines are coupled and the transformer is placed in the middle of the line, as shown in the simplified view of Figure 1.

A distribution transformer model was used and described in detail in [1].

The insulators were represented by switches (primary, secondary and neutral to ground) with the Vxt characteristic curves shown in Figure 2. Those curves were calculated using the standardised lightning impulse waveform (1,2/50 μs). The flashover dependency upon the voltage crest value was modelled according to the integration method presented in [2].

The poles, separated by an interval of 30 m, are labelled as *D1, D2, ...* and *E1, E2, ...*, in Figure1. Ground resistances of consumers and poles were included. Three different groups of grounding resistance values were selected: low (10 Ω for the consumers and 25Ω for the grounded poles), medium (100 Ω for both consumers and poles) and high (300 Ω for consumers and poles). Two different conditions for ground resistances of the poles were considered: effectively grounded (each 300m) and not effectively grounded poles. The resistances of not effectively grounded poles were considered to be twice the values of that of grounded poles, in agreement with [3].

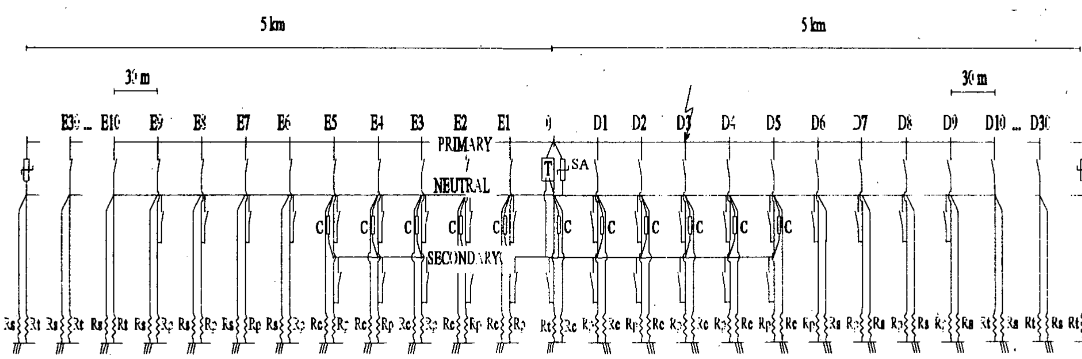


Figure 1 - System topology and main components. T: transformer; SA: primary surge arrester. C: consumer loads.

The model for representing the consumer load, connected between phase and neutral, consisted of a resistor of 30 Ω in parallel with a capacitance of 4 nF. The impedance of this simple model has a reasonable agreement with the absolute value of the impedance of the model presented in [4], obtained for a particular installation. A typical VxI curve was used for representing the characteristic of the primary ZnO arrester. For all the SPDs, a constant residual voltage of 1000 V was assumed for any current.

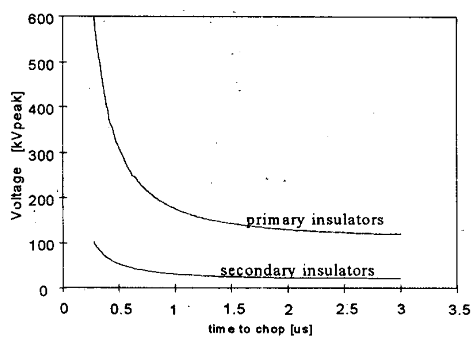


Figure 2 - Vxt characteristic curve for primary and secondary insulators.

Two different amplitudes were considered for the lightning current: 45 kA and 90 kA. According to [5], in Brazil the mean value of the amplitude of the first lightning stroke is about 43 kA, while the value 90kA is exceeded in 5% of the events. In the simulations the current was represented by a triangular waveform with times to crest varying according to its amplitude (2.25μs for 45 kA and 4.5 μs for 90 kA). In all cases the time to half-value was assumed as 80 μs.

3 RESULTS

The simulations were performed with combinations of the following parameters: grounding resistances (low, medium and high); current amplitudes (45 kA and 90 kA) and the distance between the transformer and the lightning strike point (90 m, 180 m, 300 m, 600 m, 900m, 1200 m and 1500 m).

The following situations, illustrated in Figure 3, were investigated regarding the installation points of SPDs on the secondary circuit:

- G1: SPDs at the transformer terminals;
- G2: SPDs at the transformer terminals and at the ends of the line;

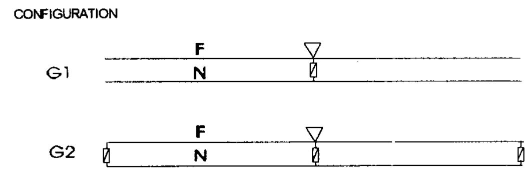


Figure 3 – Configurations of the LV line. Simplified diagram showing just one phase.

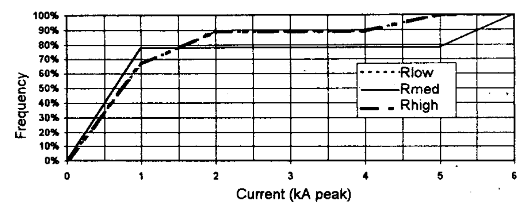


Figure 4 - Cumulative frequency of peak current at the SPDs. LV network configuration: G1. Stroke current: 45 kA

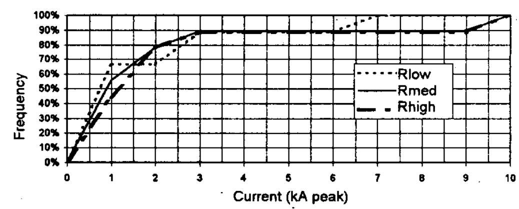


Figure 5 - Cumulative frequency of peak current at the SPDs. LV network configuration: G1. Stroke current: 90 kA

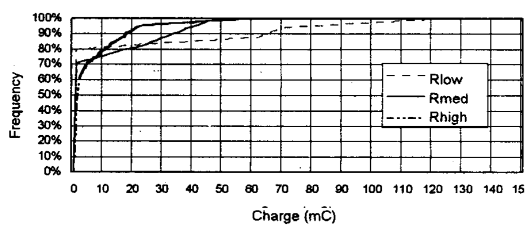


Figure 6 - Cumulative frequency of charge at the SPDs. LV network configuration: G1. Stroke current: 45 kA

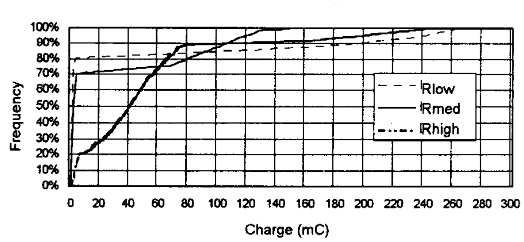
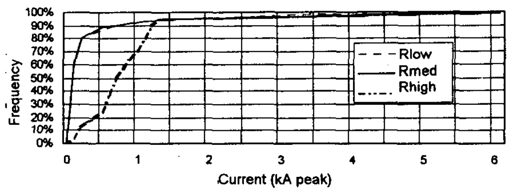


Figure 7 - Cumulative frequency of charge at the SPDs. LV network configuration: G1. Stroke current: 90 kA



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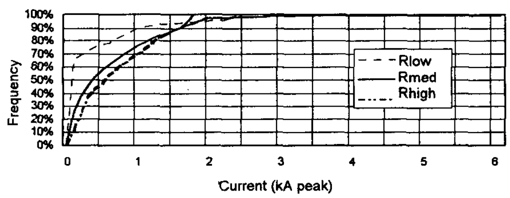
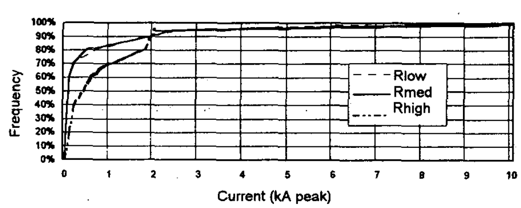


(b)

Figure 8 - Cumulative frequency of peak current at the SPDs.
LV network configuration: G2. Stroke current: 45 kA.
(a) SPD placed at the transformer (b) SPD placed at LV network ends.



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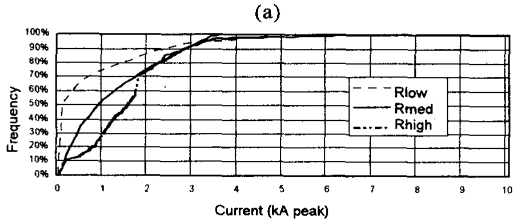
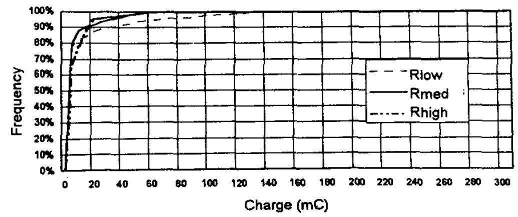


(b)

Figure 9 - Cumulative frequency of peak current at the SPDs.
LV network configuration: G2. Stroke current: 90 kA.
(a) SPD placed at the transformer (b) SPD placed at LV network ends.



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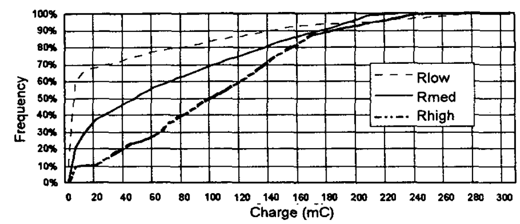
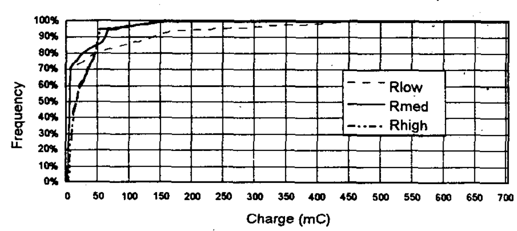


(b)

Figure 10 - Cumulative frequency of charge at the SPDs.
LV network configuration: G2. Stroke current: 45 kA.
(a) SPD placed at the transformer (b) SPD placed at LV network ends.



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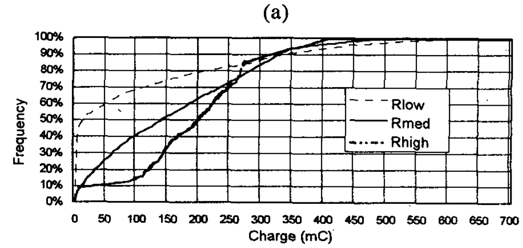

(b)

Figure 11 - Cumulative frequency of charge at the SPDs.
LV network configuration: G2. Stroke current: 90 kA
(a) SPD placed at the transformer (b) SPD placed at LV network ends.

4 DISCUSSION

The simulations allowed an evaluation of the crest value of currents and amount of charge absorbed by SPDs considering a typical low-voltage distribution system and some configurations considering the installation points of the SPDs on the low-voltage network.

The installation of SPDs at the LV terminals of the transformers is the natural protection procedure for the utilities as the transformer represents the most important device. However, the protection of the consumer entrance can only be effectively achieved by means of protectors in each service entrance. Anyway, the overvoltage magnitudes along the lines can be reduced through the installation of protectors at the end of the LV line [6]

The information relative to the stress on the SPDs is the basis for definition of surge tests. The charge drained by the protectors may be associated, for example, to the standard impulse current (waveshape 8/20 μs) with a specific charge of 17 mC/kA. This allows the adjustment of the crest value of an applied current to the SPDs in order to obtain a desired level of charge according to the obtained results.

Currently, simulations are being developed considering the LV networks composed by overhead multiplex conductors.

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