Evaluation of Stress parameters of lightning current arresters in case of subsequent strokes under consideration of travelling wave models for down conductors and earthing

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Abstract: Subsequent stroke currents 0,25/100µs stress the LPS. The stress of the equipment in a building is of importance when the strength of the equipment has to be considered in development of new components. Therefore a model of a building with the main components was developed and calculated using a network analysis programme. Especially the high di/dt value in case of subsequent strokes requires a insulation coordination under consideration of the induced voltages in loops between a surge arrester and the secondary equipment to be protected. For this purpose a model is described and the conclusions for both conventional connected and V-shape connected class I lightning current arresters are compared by calculation of the current distribution and voltages at secondary equipment.

Keywords: Arrester, subsequent stroke, modelling

1. Introduction

A LPS is designed according to the parameters of lightning [1]. The 10/350-impulse as well as the 0,25/100 impulse are used for the simulation of a LPS. The LPS components are tested in laboratory mainly with the parameters of the first stroke as shown in [1] with I,Q W/R and T2. When a subsequent stroke hits a LPS it is important to know which stress will be applied to the components. The answer can be found by a computer simulation of the LPS with its system component models. The strength of LPS against subsequent strokes can derived from the results.

2 Models for LPS-Components

Fig 1 shows a model for the LPS components of a 30 m tall building including the main electrical installation. In the TT-net a N-PE lightning current arrester and 3 phase arresters are installed to simulate the stress of the arresters.

2.1 Down conductor

Due to the rise time of the subsequent stroke of 0,25µs the modelling of the down conductor requires the representation of a travelling wave model. This model is based on segments of transmission lines with a length of 5 m. Each of the 5 m long segments has a constant impedance which depends on the height of the segment above earth according to [2] . The travelling wave impedance of a vertical cylindrical conductor above ground is shown in fig. 2.1.1.

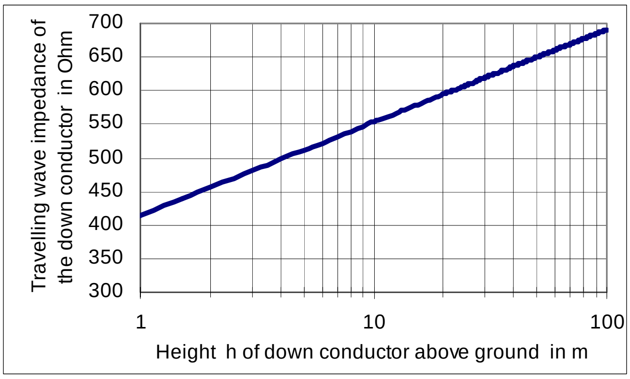


Fig.2.1.1 Travelling wave impedance of a vertical cylindrical conductor above ground depending on the height above ground.

2.2 Earthing

The earthing system is represented as a earthing rod. As shown in [3] a travelling wave model for a rod can be derived from the assumption of a cylindrical conductor which is represented using a lattice circuit. Fig 2.2.1 shows the principle equivalent circuit. Fig. 2.2.2 shows the result of a sample calculation when a subsequent stroke current of 50 kA peak value is injected. Due to this

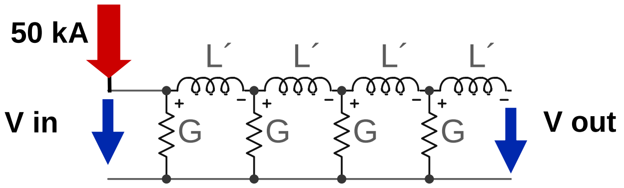


Fig. 2.2.1 Basic equivalent circuit of a cylindrical vertical earthing rod. Only 4 Elements of 51 Element are shown. L´=1µH/m G´=0,0158S/m. Total length:50 m. Travelling time 1,5 µs. DC Resistance =1.23 Ohm.

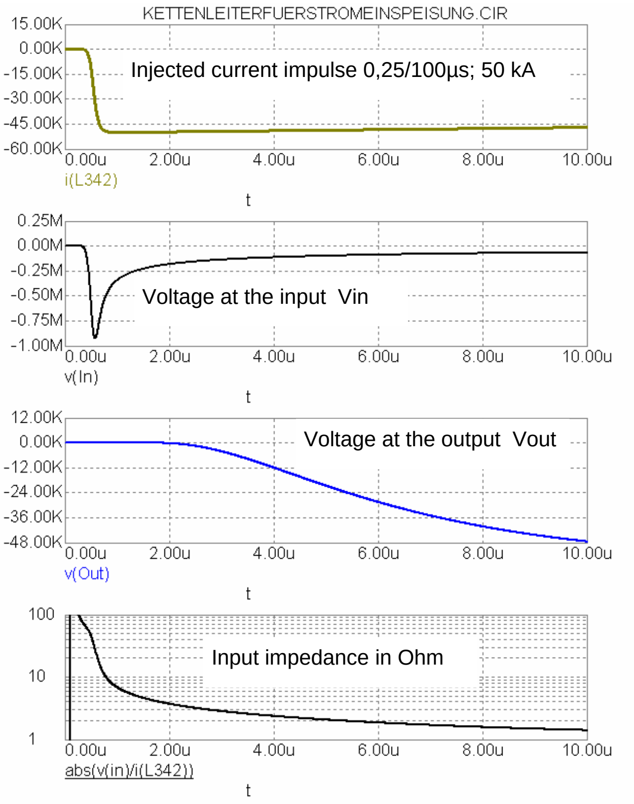


Fig. 2.2.2 Behaviour of a cylindrical earthing rod according to data as shown in Fig. 2.2.1.

behaviour the transient impedance of the earthing rises up to high value of some 100 Ohms in the front of the subsequent stroke current and decreases with increasing time down to the DC value of the earthing resistance.

2.3 Lightning current arresters

The class I lightning current arresters are represented by own models which are developed to operate even under very fast transient voltages in the ns range. This was necessary because the transient voltage at the phase arresters is really very fast when the N-PE spark gap fires. Therefore a model with high stability and very fast action in the ps range was developed and carefully tested. The arc voltage of the spark gap is represented using network

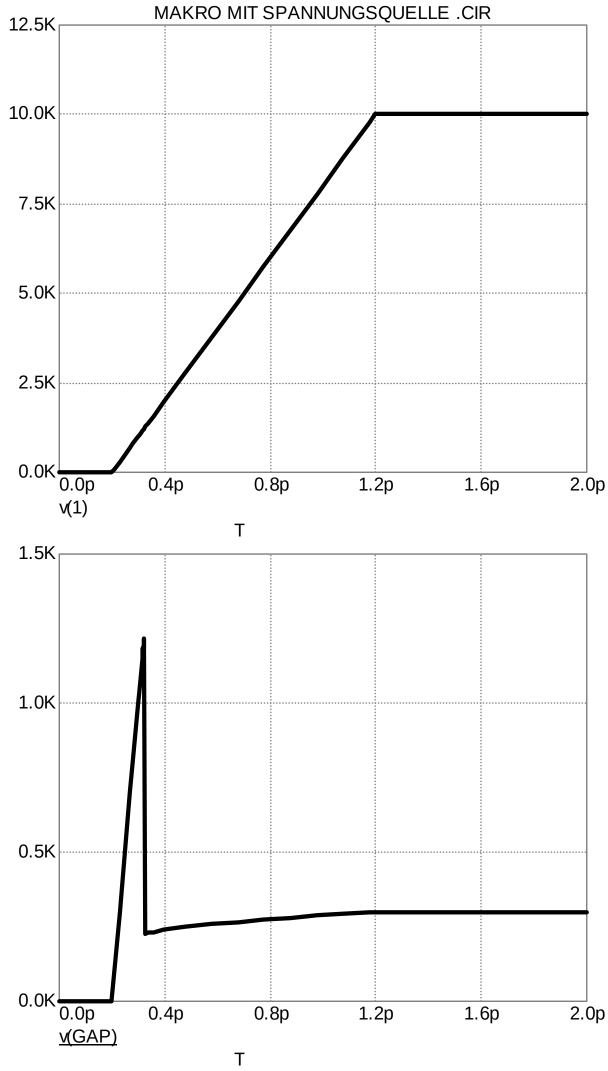


Fig. 2.3.1 Behaviour of a spark gap arrester using a fast model under an applied voltage impulse of 1 ps rise time.

elements which were derived from comparison with measurements of the arcing voltage at the used class I arresters. Fig 2.3.1 shows an example of the performance of this spark gap model.

2.4 Over voltage arresters

Over voltage arresters can be easily represented using the models of the Varistors supplied by the manufacturer. Such models are includes in the model libraries of network simulation programmes.

2.5 Cable and transformer

The cable to the power transformer is represented by a

transmission line with constant impedance.
The transformer is represented with the resistance and the stray inductance of the low voltage winding. Any coupling to the high voltage windings is not foreseen.

3 Simulation

With the models described before, a computer simulation using a network analysis programme [4] was performed to verify the stress parameters of the arresters. Fig 3.1 shows the circuit. Fig 3.2 shows the calculated currents in the arresters. In case of subsequent stroke 0,25/100µs, travelling waves determine the shape of the currents in the arresters. The main reason for the travelling waves was found in the model for the earthing and in the model for the cable to the transformer. The model for the down conductor does not influence the current shape in this example. One can obtain similar results when the down conductor is represented by an simple inductance instead of a detailed model with segments of transmission lines with particular constant travelling wave resistance. If a first stroke current 10/350µs is injected, quite smooth current shapes can be found in comparison to the results in case of a subsequent stroke as shown in fig.1. Table 1 shows the relevant stress parameters for comparison. The main difference in the stress parameters is the dynamic stress, di/dt and du/dt of the arresters under the subsequent stroke. It has been shown in [5] that even under such fast transients the spark gaps of lightning current arresters with multiple spark gaps can successfully oper-

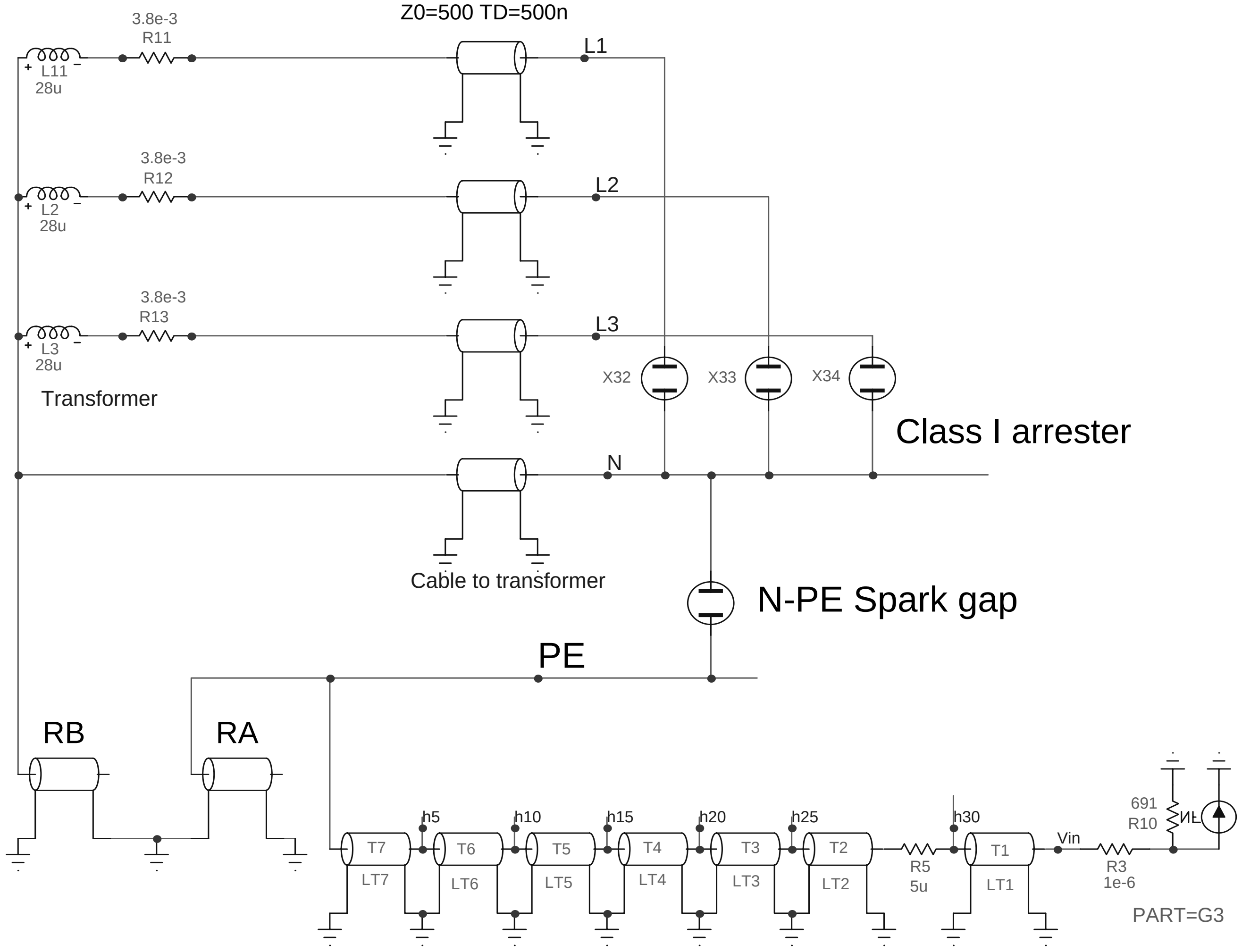
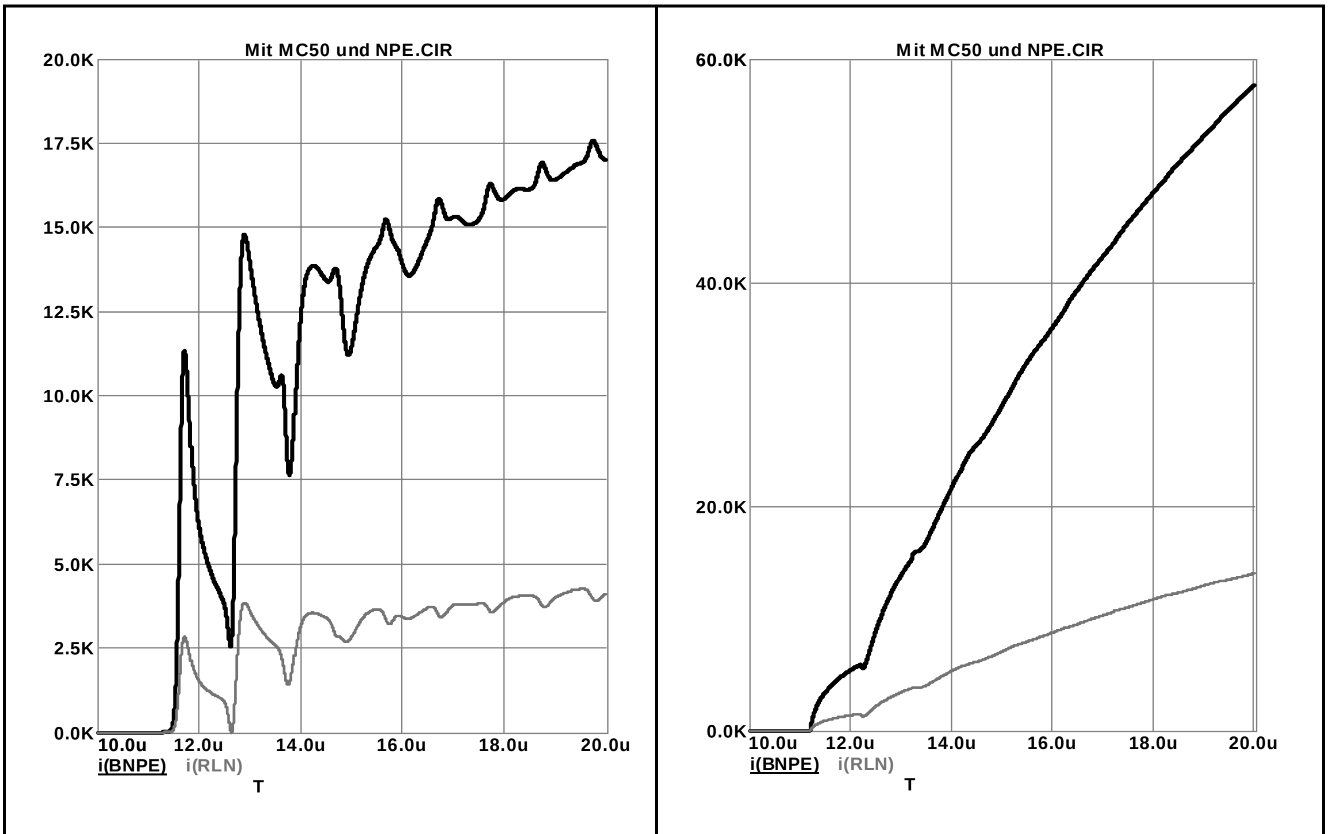


Fig 3.1 LPS-Components of a building with electrical main installation.

T2..T7: Model of the down conductor of 30 m length.
T1,R3: Representation of a lightning channel
R10: Termination of the lightning channel
G3: Current source
RA: Local ground
RB: Station ground



Subsequent stroke 0,25/100µs, 50 kA	First stroke 10/350µs, 200 kA
upper: Current in N-PE spark gap lower: Current in class I phase arrester	upper: Current in N-PE spark gap lower: Current in class I phase arrester

Fig.3.2 Results of simulation of the circuit in fig.3.1. for local ground and station ground 1,23 Ohm each.

	di/dt, max.		**du/dt, max.**		$\hat{i}$		$Q = \int \lvert i \rvert dt$		$\frac{W}{R} = \int i^2 dt$		**Current in earthing i_{max} 1)**	
	kA/µs		kV/µs		kA		As		kJ		kA	
Arrester	N-PE	B	N-PE	B	N-PE	B	N-PE	B	N-PE	B	R_A	R_B
0,25/100 50 kA	96	21	29	In-finit	19,5	4,5	3,6	0,8	41,9	2,4	46,5	20,3
10/350 200 kA	8	1,8	0,7	In-finit	94	23	49,6	11,4	2500	145	94	130

Table 1 Calculated stress parameters of Class I lightning current arresters in a system as shown in fig.1. for injection of subsequent stroke current 0,25/100µs and first stroke current 10/350µs.

1) The imax value appears at different times.

2) Infinite: The rise time is given by the resolution of the computer simulation.

ate and provide the required protection level at the terminals of the arrester. The other stress parameter are lower in case of a subsequent stroke compared to the first stroke. One has to take into account the value of 50 kA for subsequent stroke and 200 kA for the first stroke. Lightning current arresters are designed for such values, e.g. 50 kA 10/350 for the phase arresters and 125 kA for a N-PE gap as shown in [6].

The current in the Station Ground as well as in the local ground are shown in fig. 3.3. There is a clear indication that the modelling of the earthing rod by a lattice circuit leads to a much higher rate of rise of the current in the local ground. The current in the individual arresters is shown in fig. 3.4 in a larger time range.

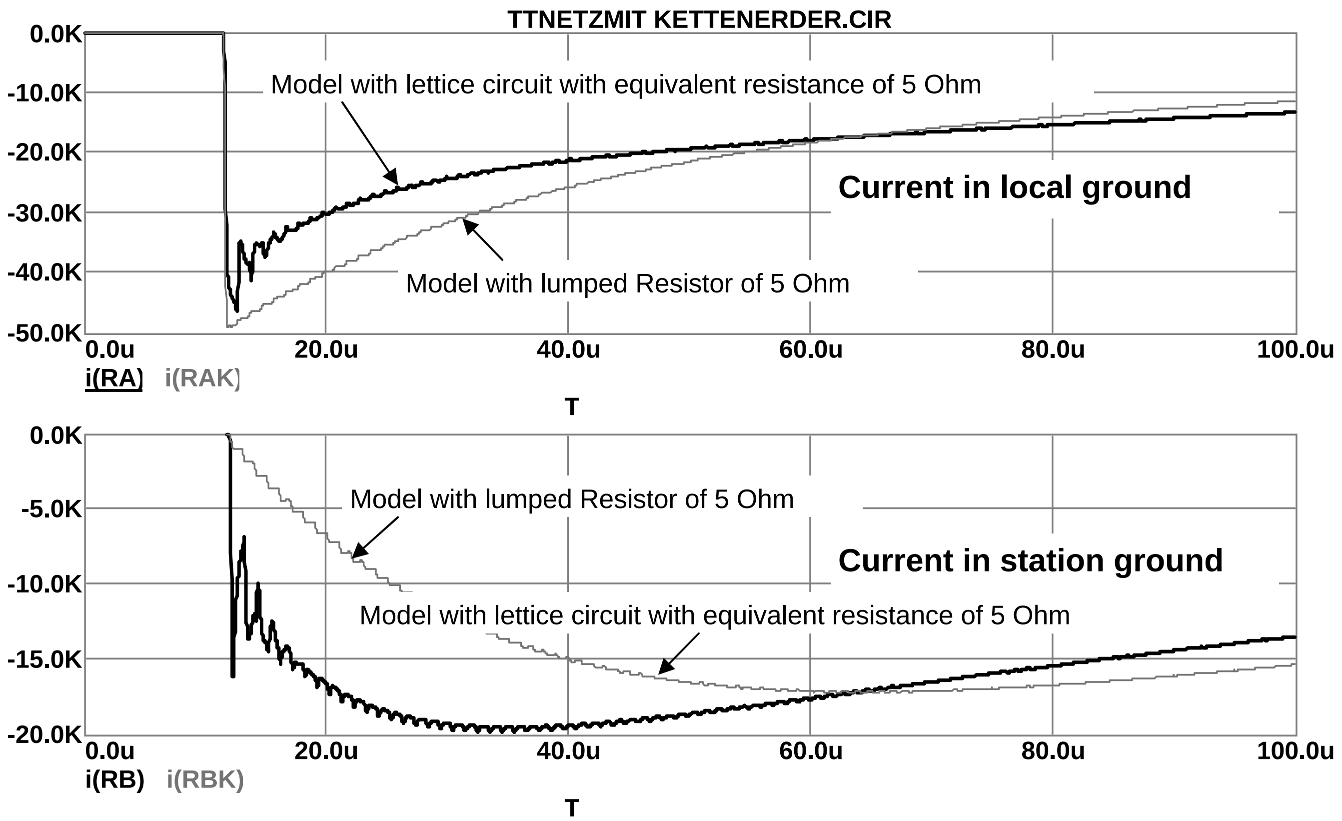


Fig.3.3 Calculated currents according to fig. 3.1 in station ground and local ground with 5 Ohm each. Injected current

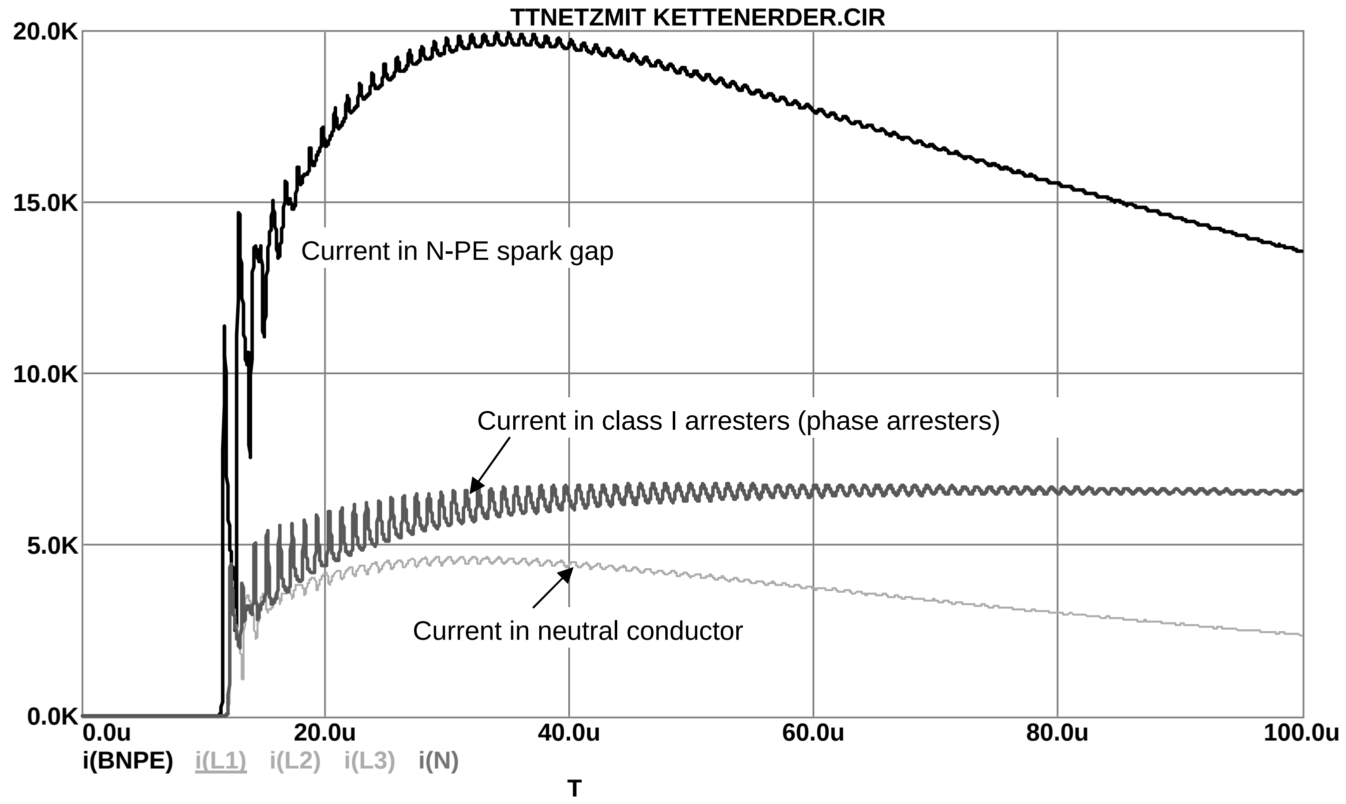


Fig.3.4 Calculated currents according to fig. 3.1. Station ground and local ground 5 Ohm each. Injected current 0,25/100µs, 50 kA.

6 Conclusions

The calculation of the stress parameters of arresters in a building which is struck by a subsequent stroke can be done with commercial available programmes. The system components have to be represented by suitable models. In this paper a modelling with travelling wave models was chosen. Any radiation of electromagnetic fields is not taken into consideration.

The down conductor can be represented by a transmission line with segments of constant impedance. But the results have also shown that a simple inductance provides similar results.

The earthing has to be carefully represented. An earthing rod can be represented by a lattice circuit and provides different results. The dynamic resistance determines the voltage at the earthing. Therefore the earthing model plays a major role for the calculation of the stress of surge arresters.

Surge arrester models have to be developed for very fast operation because the N-PE-spark gap operates first and creates a very fast transient voltage which appears at the class I arresters. Such a model has to represent the arcing voltage also.

In case of a subsequent stroke the current in the arresters shows travelling waves. The di/dt and du/dt parameters are high compared to the first stroke 10/350µs. The other values a charge and specific energy are low compared to a 10/350µs impulse.

However one has to consider always the fact that a subsequent stroke follows the first stroke and adds to the total stress. The class I arresters are designed and tested according the stress which occurs at the first stroke. The additional stress caused by a subsequent stroke is normally covered by the capability of the class I arrester when it is designed for a peak current of 200 kA.

7 Acknowledgment

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8 References

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