NETWORK MODEL FOR TRAINING IN APPLICATION OF SURGE PROTECTIVE DEVICES

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Abstract: A portable network model for training in application of surge protective devices that shows the performance of an internal lightning protection system during a lightning stroke is described. The model is designed for the engineers and vocational education. It allows to show the effects of the lightning current commutation between the surge protective devices (Class I, II and III arresters), the follow current interruption, the lightning current distribution by using a long or short power supply cable and the voltage-time behaviour of spark gaps and varistors (spark over and residual voltage). The portable network model consists of a 1:10 down scaled voltage system (400/220 Volts to 40/23V, 50Hz) and a small 10/350µs surge current generator with a peak value of 500A which simulates a real 100kA lightning current impulse.

Keywords : Portable network model for training, surge protective devices (SPD), Class I -, Class II - and Class III arrester, over voltage protection, spark over voltage, follow current.

1 INTRODUCTION

The installation of surge protective devices (SPD) in power systems requires a fundamental knowledge. This knowledge can be achieved by training courses where the theoretical background could be explained. For the practical engineer who deals with planning and installation as well as for education of apprentices we have found that a network model is very useful since the

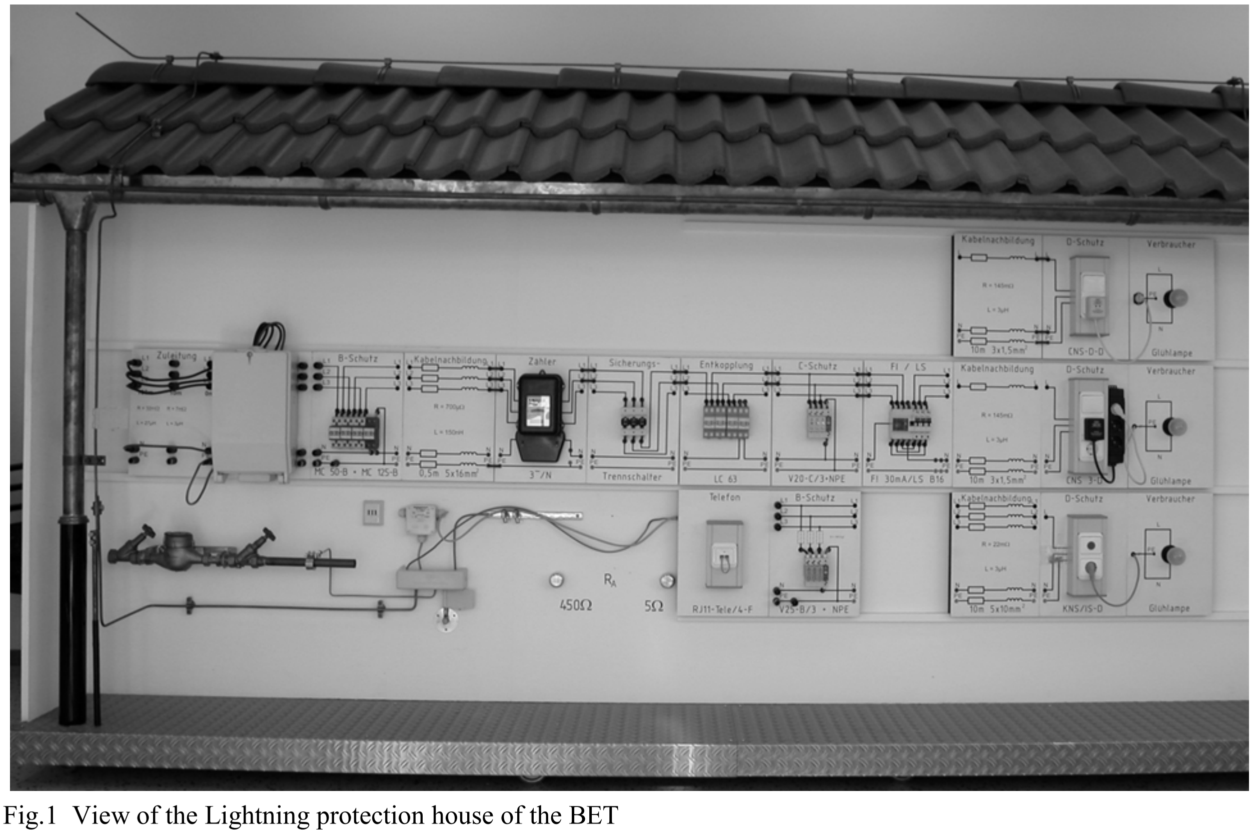

Fig.1 View of the Lightning protection house of the BET

teacher can demonstrate various effects. For this in the BET – Blitzschutz und EMV Technologiezentrum – (means Lightning protection and EMC technology centre) a natural size network model according to figure 1 [1] was developed. This model shows a complete electrical installation including the external and internal lightning protection system.

The disadvantage of that natural size model is its large extent, so it is not transportable. The advantage is the design which allows the direct current injection from the adjacent surge current generator of the BET [2] according to figure 2. For transportable and flexible use e.g. for education and demonstration during fairs it was necessary to develop a portable network model with protective low voltage for training as shown in figure 3.
The portable model includes a 1 kA, 10/350µs surge current generator to show the performance of the lightning protection system.

2 THE COMPONENTS OF THE NETWORK MODEL

The lightning protection network model consists of a 40/23V 50Hz 3 phase TT system. With 23V the safety of persons is given. The voltage scale related to 400/230V of the model is 1:10.
The earth resistance of the power supply is 1.5Ω. The prospective short circuit current of the power supply is 20A Peak and simulates 4kA. So the current scale of the model is 1:200.
The cable between the power supply and the house connection box is configured with two different terminals named “transformer close” and “transformer far”. “Transformer far” simulates a 150m 4 x 95mm² cable. “Transformer close” simulates a very short cable so the inductance and the resistance can be neglected.
The main fuses, the current counter, the fault-current protective switch and the fuses of the power distribution are only given as their symbols.
The decoupling elements like inductors or cable impedances are available.
To show the performance of the surge protective devices a surge current generator is built in and generates a current impulse 10/350µs [3] with a peak value of 500A as shown in figure 4 which corresponds to a natural impulse of 100kA and represents the part of the lightning current which flows through the power supply cable to the station ground. It makes no sense to show the part of the lightning current which is flowing to local ground so a 100Ω local earth resistor is used that shows the worst case of a high impedance grounding system.

The most important components of the network model are the surge protective devices of Class I, Class II and Class III arresters. They cannot be used in the original design. Because of the voltage scale of 1:10 the level of

Fig. 2: Surge current generator of the BET

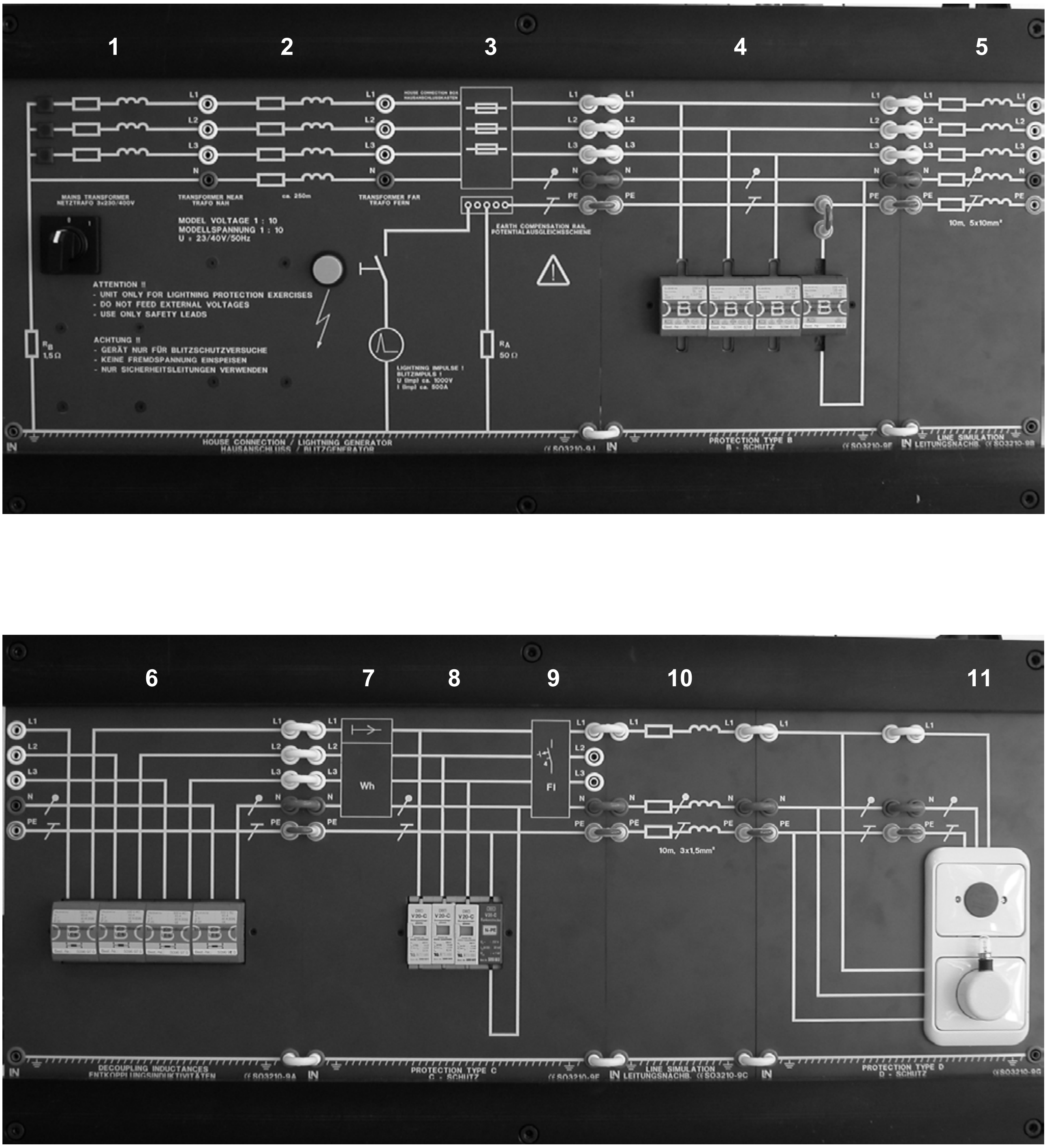

Fig 3: Network model for training

1 Power supply	2 Power supply cable
3 Main fuses with bonding bar	4 Class I lightning current arrester
5 10m cable 5 x 95mm²	6 Decoupling inductances
7 Current counter	8 Class II over voltage protection devices
9 Fault-current protective switch	10 10m cable 3 x 1.5mm²
11 Load (filament lamp) with Class III SPD	

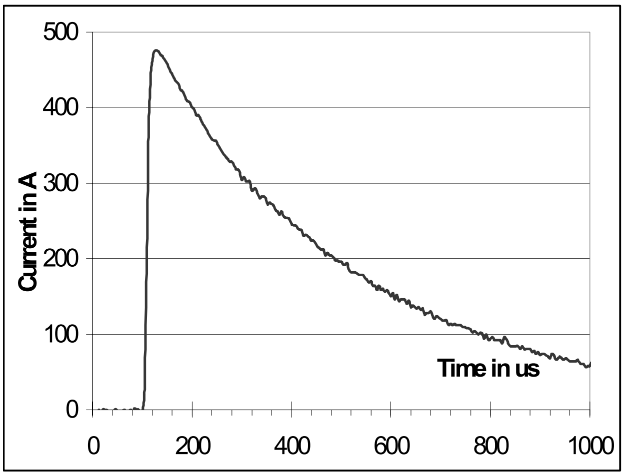

Figure 4: Lightning current impulse of the surge current generator (500A 10/350µs) if long power supply cable and all SPDs are installed.

Figure 5: Current flow through the N-PE spark gap arresters if long power supply cable and all SPDs are installed.

the spark-over voltage of spark gap arresters and the residual voltage of varistor arresters are scaled down by 1/10.

A major problem was given on the fact that there is no air spark gap is switched below a spark-over voltage of 352V (Paschen's minimum).

So the function of the original surge protective devices with spark-over voltages in ranges of kV are represented with electronic circuits as thyristors etc, which show basically the same behaviour as the originals.
The network model consists of a 3+1 mounting of Class I lightning current arresters and Class II over voltage protection arresters and also one Class III surge protective device.

At the right end of the house installation in fig. 3 a filament lamp is shown. It will be destroyed by the lightning current impulse of the generator when the installation is tested without any surge protective devices and it works continuously when tested with the arresters.
The handling of the model is very easy. So each component of the house installation is placed on a separate pluggable panel. The lightning current impulse is released by pressing only one button.

3 PERFORMANCE OF THE NETWORK MODEL

With the lightning protection network model it is possible to demonstrate the performance of the surge protective devices during a lightning stroke. In this case, only the part of lightning current is significant that flows from the main equi potential bonding bar through the power supply cable to the station ground.
The model is designed for the vocational education for electricians and installers. So the easiest test is to show the performance of the filament lamp during a lightning stroke by an installation with and without any surge protective devices.

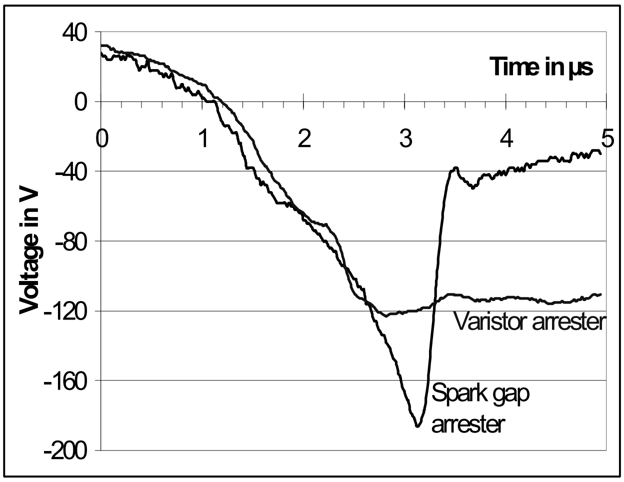

Figure 6: Voltage oscillogramms of a varistor arrester and a spark gap arresters

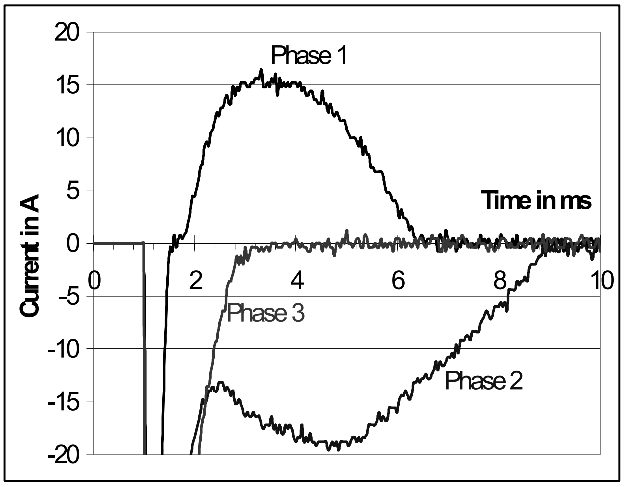

Figure 7: Lightning current distribution by a long power supply cable (all SPDs are installed).

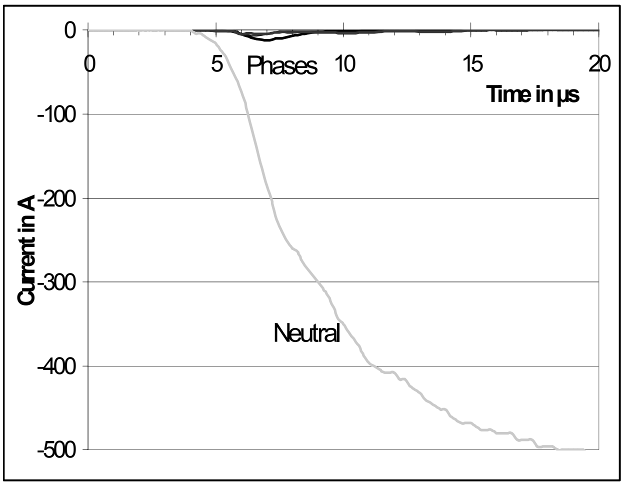

Figure 8:Lightning current distribution by a very short power supply cable (all SPDs are installed).

But the model can show many more. So it is possible to show the current and voltage oscillogramms of the spark gap arresters and varistor arresters. It is distinct visible that at first the lightning current flows through the Class III arrester and commutates to the Class II arrester before it commutates into the Class I spark gap arresters as shown in figure 5. The difference between the sparkover voltage of a spark gap arrester and the voltage oscillogramms of a varistor arrester is shown in figure 6.

Furthermore it is possible to show that the follow current is flowing through a spark gap arrester that is connected between phase and neutral and that the follow current is extinguished by the arrester. This performance is caused by the phase angle triggered input of the lightning current impulse. The three different follow current oscillogramms in figure 7 are caused by the 3 phase net. By reason of the terminals of "transformer close" and "transformer far" it is possible to show the effect of current balancing by long power supply cables. So in figure 8 and 9 the lightning current partitioning in the power supply cable is shown by a very short power supply cable and a long one. The reason for that is the damping of the transformer coils and depends on the length of the power supply cable. By increasing the length of the cable the values of the resistance and inductance increases too and so the influence of the transformer coils decreases. In the opposite the influence of the cable impedance decreases by a short cable. Therefore the value of resistance and inductance of the neutral can be neglected. The damping effect of the transformer coils is at its maximum and so the lightning current is displaced to the neutral. In this arrangement it is possible that the lightning current arresters between phase and neutral are not triggered and there is no follow current.

It is not possible to show the part of over voltage causing the magnetic influence of the lightning current.
It is not possible to show the damage of the electric installation without any surge protective devices due to the mechanical force of a lightning stroke.
And it is not possible to show that a damage of a class II or III arrester causes a current impulse which is higher than the maximum discharge current of the device. Because of the safety all spark gap arresters and varistor arresters are able to discharge the full lightning current impulse with a peak value of 500A. The reason for this is that the interchange of any damaged arresters is too expensive for a school.

4 CONCLUSION

It is not possible to show all effects in a building installation during a lightning stroke.
But it is possible to show the basic effects as the balancing of lightning current parts and the performance of surge protective devices.
The model gives a lot of help to understand the mode of working of an internal lightning protection system. This model contributes for the better education of engineers in practical applications. It is a useful tool to accompany the theory based on training courses.

5 REFERENCES

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