



EVALUATION OF ARRESTER'S PROTECTION LEVELS DURING LIGHTNING STRIKES TO OVERHEAD MEDIUM VOLTAGE LINES

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Abstract: This paper present an evaluation of overvoltages in low-voltage LV installation in buildings in cases of direct lightning strikes to overhead medium voltage lines. The study considered typical power systems with low- and medium voltage surge arresters. The calculation have been performed using the EMPT-ATP

1. INTRODUCTION

The direct lightning strikes to medium voltage MV lines are not so frequent in distribution systems but their effects are very severe. The limitation of these dangerous assures lightning and overvoltage arresters in MV and LV lines.

Analysis of lightning overvoltages that occur in electric installations in buildings requires the careful modeling of power systems, especially MV/LV transformer and arresters. These models must hold over the frequency range typical for the phenomena associated with the lightning strike.

In calculation the EMPT - ATP (Alternative Transients Program version of Electromagnetic Transients Program) was used. This program, which has now become standard in power system simulation, allows simulating electric transients by integrating systems of ordinary differentions and partial derivative equations with the results that they can successfully handle the problems describe above.

2. SYSTEM CONFIGURATION

In number of cases electric power substation is supply from MV overhead transmission line. Especially, this part of electric power system is particularly menace from the lightning. MV overhead transmission lines haven't got a neutral wire and they are putted frequently on open terrain. Only the grounded pylons with good matched line isolators are factor that decrease lightning surges in these lines.

In calculation, we considered the following systems: medium-voltage (MV) overhead line, MV/LV transformer and LV power overhead line connecting

the distribution transformer and electric installation in structure.

In theoretical model the following assumption were made:

- The characteristic impedance Z_0 (surge impedance) of the line is normally in the range 400 - 500Ω for the conductor and in calculation we take the value 400Ω.
- The effective impedance of the lightning channel is high and in calculation the lightning current was practically considered as an ideal current source.
- The earthing resistance of transformer station is 2 Ω.
- In building, the conductor PEN is connected to the earthing system of building.
- The earthing resistance of building is 10 Ω.
- A high frequency model of transformer was used with capacity coupling between primary and secondary windings.
- The surge protective devices (SPDs) are located at the primary side of MV/LV transformer and at the entrance of underground LV line to building.

Electric power substations MV/LV in major cases work with isolated neutral point on the MVs side, but on LV side with directly grounded neutral point to the substation grounding system (transformer with the Dyn connection).

In analysis, we take the lightning current of 10 kA, shapes 10/350 and 0,25/100 for simulation the first and subsequent lightning stoke.

These lightning currents were defined by typical equation:

$$i = \frac{I_{max}}{h} \cdot \frac{(t/\tau_1)^{10}}{1 + (t/\tau_2)^{10}} \cdot \exp\left(-\frac{t}{\tau_2}\right)$$

where:

- I_{max} - the peak current,
- h - the correction factor for the peak current,
- t - time,
- τ_1 - front time constant,
- τ_2 = the tail time constant

Electric wiring in final user building was taken as TN-C-S system.

For the illustrative purpose the topology of of MV/LV distribution systems with SPDs is presented in Fig.1.

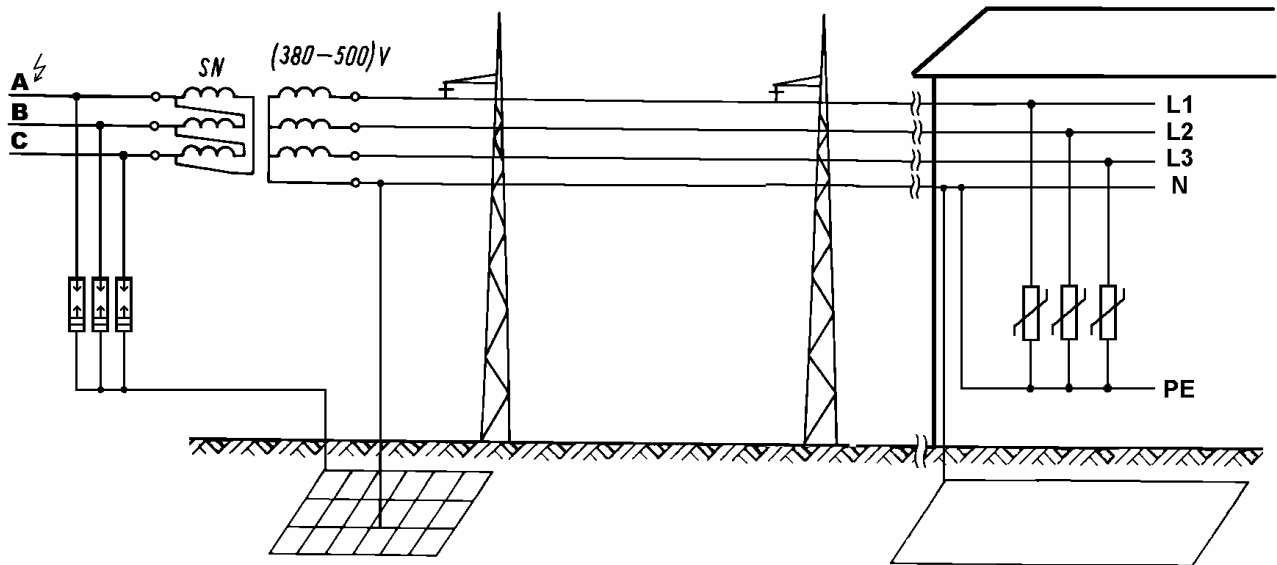


Fig.1. Circuit diagram, which is used in calculation.

The real MV/LV transformer – ABB TNOSCF 1000/15 [5] was used for computer simulation. At the initial stage of analyze transformer parameters were converted to program conditions [4]. In LV electrical installation the load was taken as clearly star connected 5Ω resistances.

ATP-EMTP is universal program for transient computer simulation in time domain. It can compute circuits with linear and non-linear elements. Major attention was paid to easy computer implementation of non-linear elements by MOV (Metal Oxide Varistor) component.

In computer simulation of lightning overvoltages in LV installation in building, metal-oxide arresters MOAs were presented as non-linear elements.

LV MOAs nonlinear V-I characteristics was taken for typical overvoltage arrester with following parameters:

- maximum continuous operating voltage 275 V
- nominal discharge current (8/20) 20 kA
- max. discharge current (8/20) 40 kA
- voltage protection level ≤ 1500 V

After measurement LV MOAs by digital oscilloscope received data was implemented to MOV component [2] in EMTP.

MV surge arresters were implemented as MOV component too [3], with added voltage-controlled switch [3]. Typical V-I curves were used for representing the characteristics of MV and LV metal-oxide surge arresters, as shown in Fig.2.

Analyzed electric power system in the ATP-EMTP was presented in Fig.3.

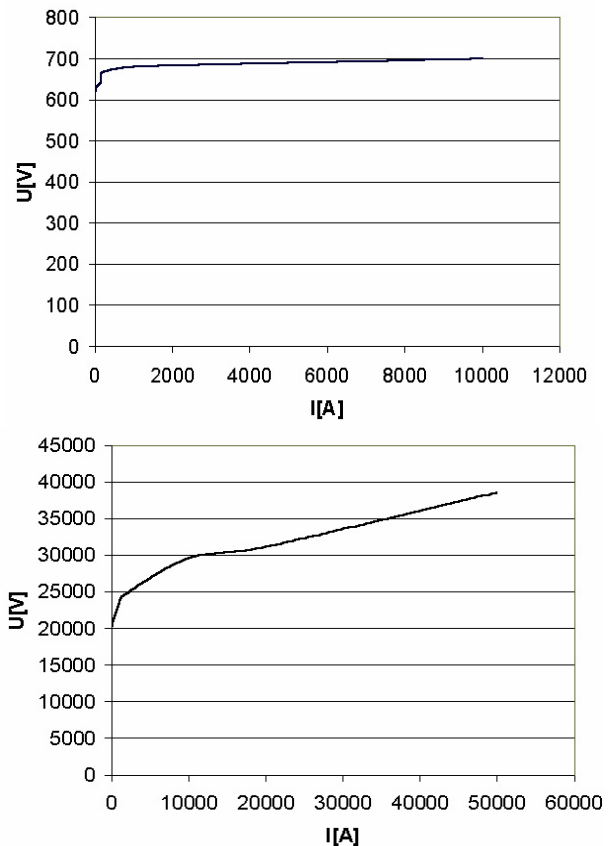


Fig.2. Nonlinear V-I characteristics of typical LV and MV metal-oxide surge arrester

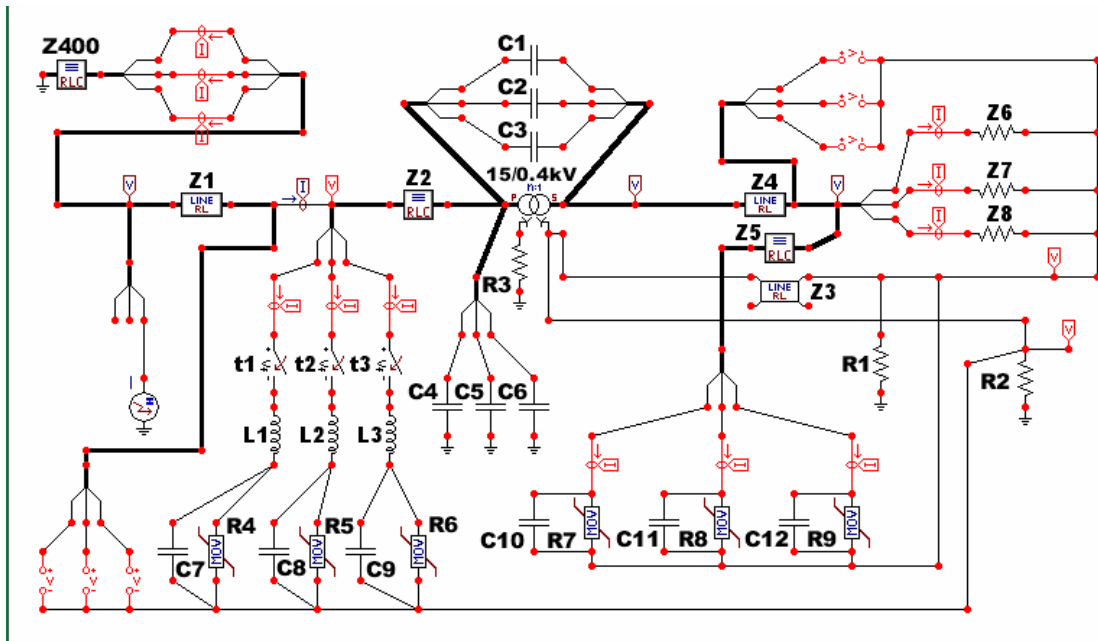


Fig.3 Analyzed electric power system in the ATP-EMTP

3. RESULTS

The study of transient behavior in electric power system was done for direct lightning strike to:

- one phase conductor of the MV overhead line,
- three phase conductors of this line.

The surge currents propagated along the lines. Next some parts of these currents appeared at the primary side of MV/LV transformer and MV arresters operated. The surge currents flowed to the earthing system of transformer and produced earth coupling between MV and LV systems. In calculation, the distance l between transformer and building (length of LV line) was changed from 30m to 300m. Some examples of results were presented in Fig. 4, 5 and 6. Fig.5. shows the currents, which flow in MV and LV arresters for surge currents injected to one conductor of MV line ($l=30m$).

For users of LV equipment more interesting is the level of the overvoltages, which appeared in electric installation inside the buildings.

The calculated values of overvoltages on load's resistors $R = 5\Omega$ did not exceed:

- 2000V - for strike in one conductor of MV lines (Fig.5.),
- 100 V – if the surge currents were introduced simultaneously to three conductors of MV line (Fig.6.)

In analyzed power electric systems the LV MOAs did not reduced the potential differences between the conductors of LV installation and true earth (Fig.5 and

6). In the worst case, when the surge currents were injected to three conductors, the values of these potential difference exceed 40 kV.

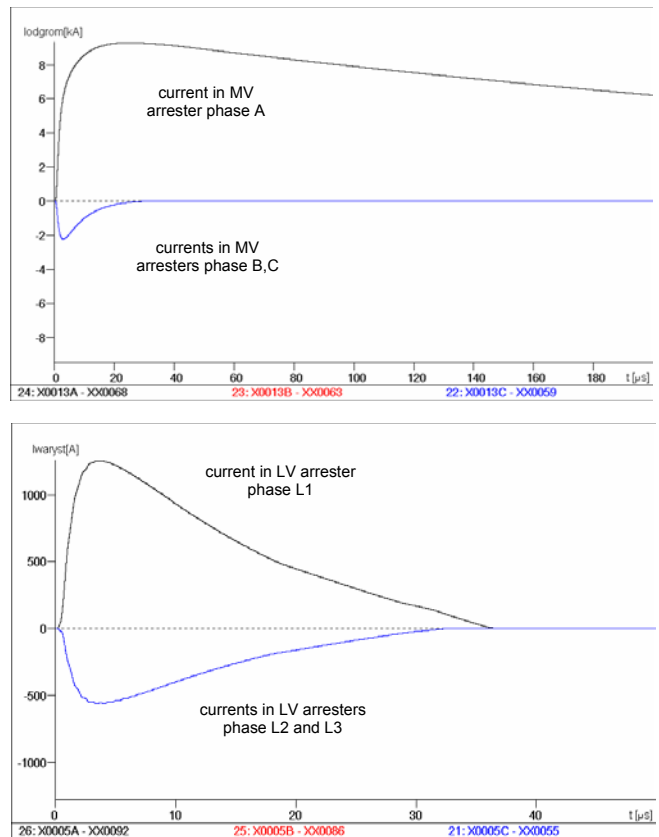


Fig.4. Surge currents in MV and LV arresters (surge current introduced in one wire of MV line)

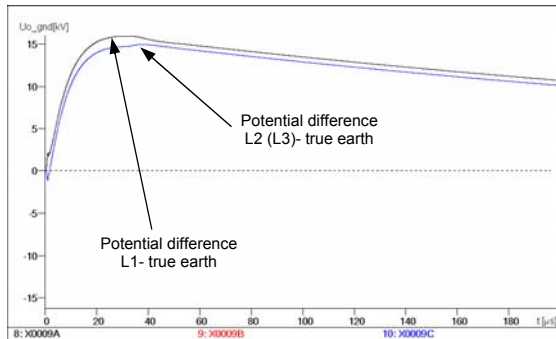
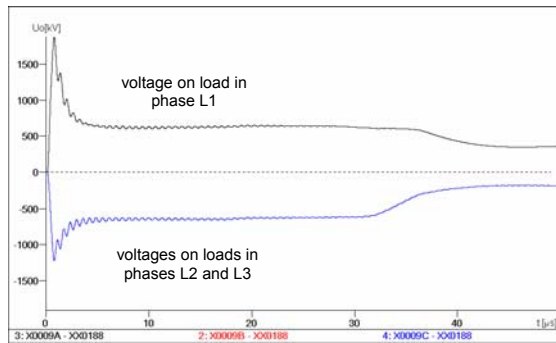


Fig.5. Voltages on the loads and potential differences between LV phase conductors and through earth (surge current introduced in one wire of MV line)

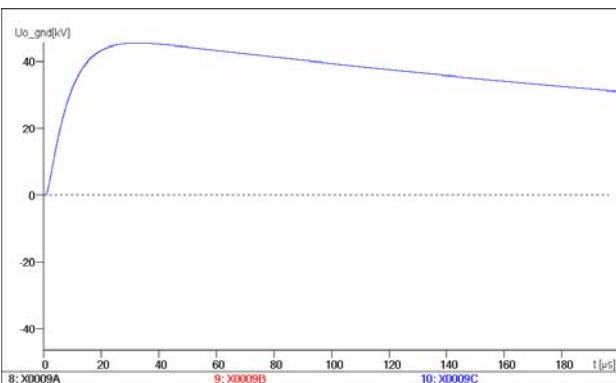
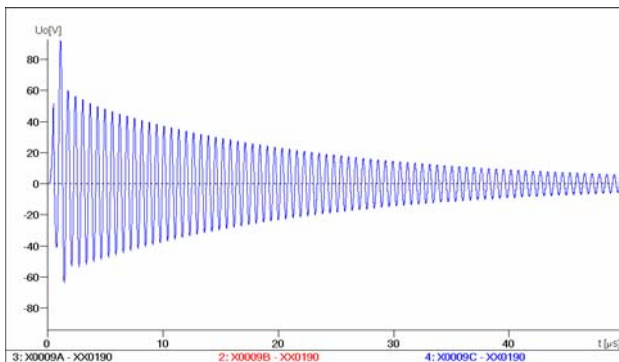


Fig.6. Voltages on the loads and potential differences between LV phase conductors and through earth (surge currents introduced into three wires of MV line)

4. CONCLUSION

The computer simulation allowed an evaluation of voltage and current surge distribution in MV/LV electric systems, giving information about:

- currents in MV and LV arrester's,
- voltages on the loads in LV installation,
- potential differences between the LV phase conductors and trough earth.

Direct connection between surge arrester grounding and substation grounding by the MV side creates dangerous to the LV side. The overvoltages, which were caused by the surge currents in earthing system of transformer, were transferred to the LV installation. Depending on the earthing impedance values and surge currents values, this earth coupling overvoltages were much higher then the capacitive coupling through transformer.

It is impossible to avoid raise of voltage on the grounding system, but user can avoid direct interconnection between other grounding systems. If this connection is necessarily needed user should use separation transformers for over-voltage protection. Metal-oxide surge arresters don't assure high protection level of the final user devices.

References

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