OVERVOLTAGES IN LOW-VOLTAGE POWER DISTRIBUTION SYSTEMS CAUSED BY DIRECT LIGHTNING STROKES TO MEDIUM VOLTAGE LINES.

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Abstract - This paper presents an evaluation of overvoltages in low-voltage electrical installations in buildings during direct lightning strikes to overhead medium voltage lines. The study considered typical power systems with low- and medium surge arresters. The calculations have been made by the EMPT- ATP simulation program.

1 INTRODUCTION

In the most analyses, which estimated the lightning overvoltages in low-voltage (LV) power a.c. systems, the direct lightning strike to the lightning protection systems (LPS) of building is taken into account. In such case, the lightning current flows from the air-termination system through the down conductors to the grounding system of building. At this point, the surge current is divided into two components, which flow:

- down into the local earth,
- into the services entering this building (water and gas pipes, electrical power line, telephone lines) towards to distant earth.

Different character of overvoltages in LV installation appeared in buildings without LPS. In this situation, the most dangerous are the lightning overvoltages, which come from the power distribution systems. These cases are investigated in article.

2 MODELS OF MV/LV DISTRIBUTION SYSTEMS

For illustrative purpose, we considered the following systems: medium-voltage (MV) overhead line - MV/LV transformer - LV power underground cable connecting the distribution transformer and electrical installation in residential house without LPS.

2.1 Model without LV surge protective devices

At the input of LV installation, the neutral conductor is connected to the grounding system of building (earthing resistance 10Ω). At the beginning, it is assumed that there are no surge protective devices (SPD) in consumer installation. This arrangement is presented in Fig. 1.

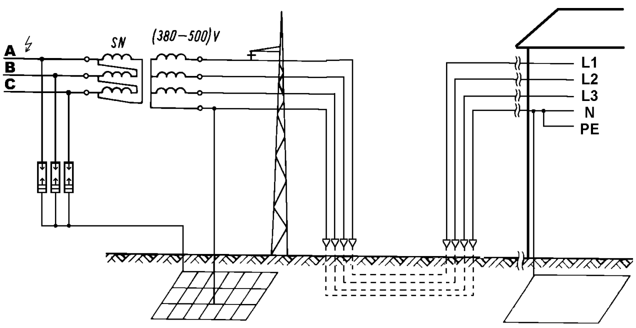

Fig.1. Typical model of MV/LV distribution systems

In most cases electric power substation MV/LV works with isolated neutral point on the MVs side, but on LV side with directly grounded neutral point to the substation grounding system (transformer 15/04 kV with the Dyn connection). The real MV/LV transformer – ABB TNOSCF 1000/15 [8] was used for computer simulation. At the initial stage of analyze transformer parameters were converted to the conditions of EMPT - ATP (Alternative Transients Program version of Electromagnetic Transients Program), which is used in theoretical analyses.

In calculation a high frequency model of transformer was taken into account with capacity coupling between primary and secondary windings.

This transformer is protected by overvoltage arresters at the primary side. The earthing resistance at this point is 2 Ω.

The characteristic impedance Z_0 (surge impedance) of the line is normally in the range 400 - 500Ω for the conductor and in calculation we took the value 400Ω.

In the analysis, the lightning currents 10 kA (peak value) - 10/350 and 10 kA - 0,25/100 10 kA (peak value) were used for simulation the first and subsequent lightning strokes.

These lightning currents were defined by typical equation:

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

In the case of theoretical model, the lightning current represents ideal current source which was connected to one or to all three phases of MV line depend on model configuration

Distance *l* between transformer and building (length of LV line) was changed from 30m to 300m.

MV surge arresters were implemented as MOV component, with added voltage-controlled switch. Typical V-I curve, which was used for representing the characteristics of MV metal-oxide surge arrester, is shown in Fig.2.

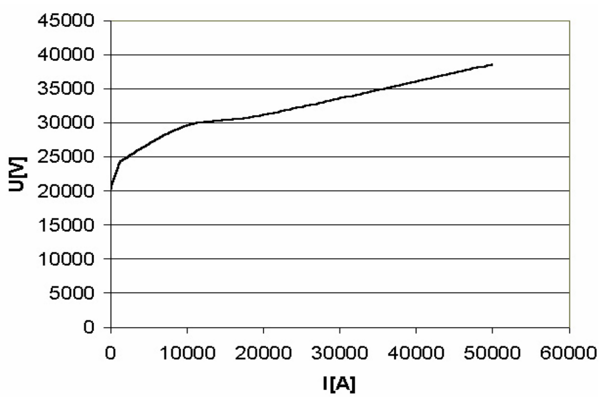

Fig.2. Nonlinear V-I characteristic of typical MV metal-oxide surge arrester

Analyzed electric power system in EMPT-ATP was presented in Fig.3. The loads of LV installation were simulated by Z_6, Z_7, and Z_8 (Z_6=Z_7=Z_8=5Ω) connected between each phase wires L1, L2, L3 and neutral wire N.

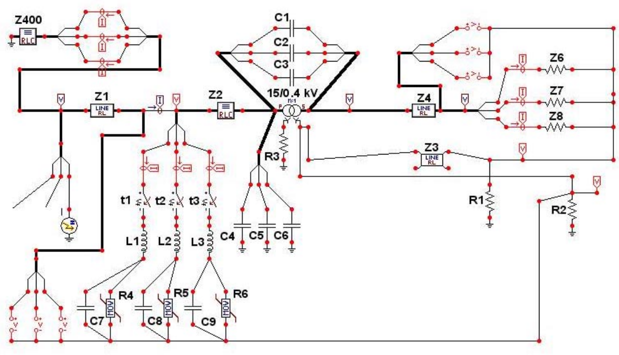

Fig.3. Circuit diagram of MV/LV system used in calculation

Some examples of results were presented in Fig.4, 5 and 6. Fig.5. shows the currents which flow in MV arresters and voltages at these arresters for surge currents injected to one conductor (phase A) of MV line (*l=300m*).

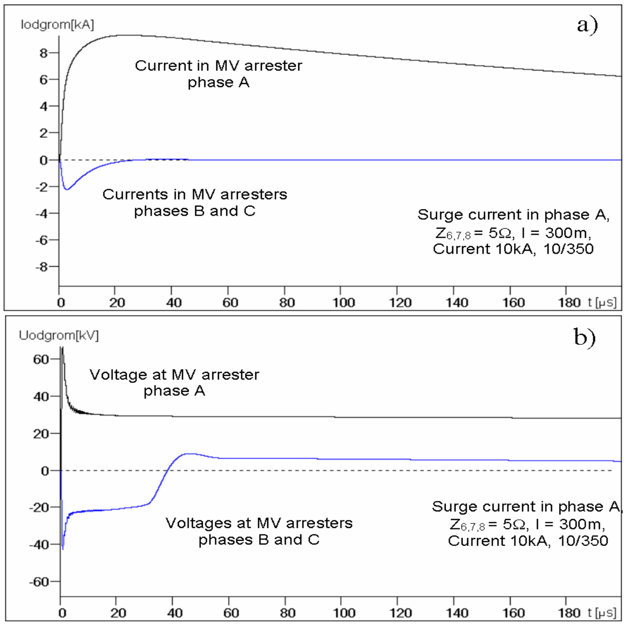

Fig.4. Currents in MV arresters (a) and overvoltages at these arresters (b).

For users of electric and electronic equipment the information about the lightning overvoltages, which appeared in LV installation inside the building, were more interesting. Overvoltages on the consumer loads and potential differences between the phase wires L1, L2, L3 and the true earth are presented in Fig. 5 and 6.

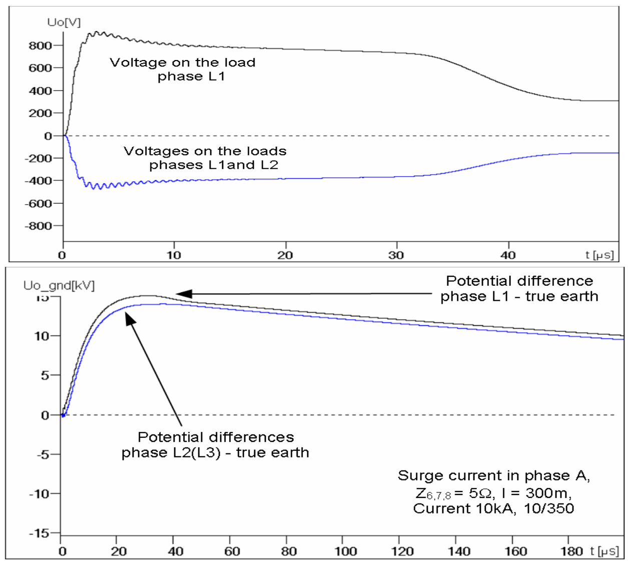

Fig.5. Lightning overvoltages on the loads and potentials differences between phase conductors (at load) and true earth.

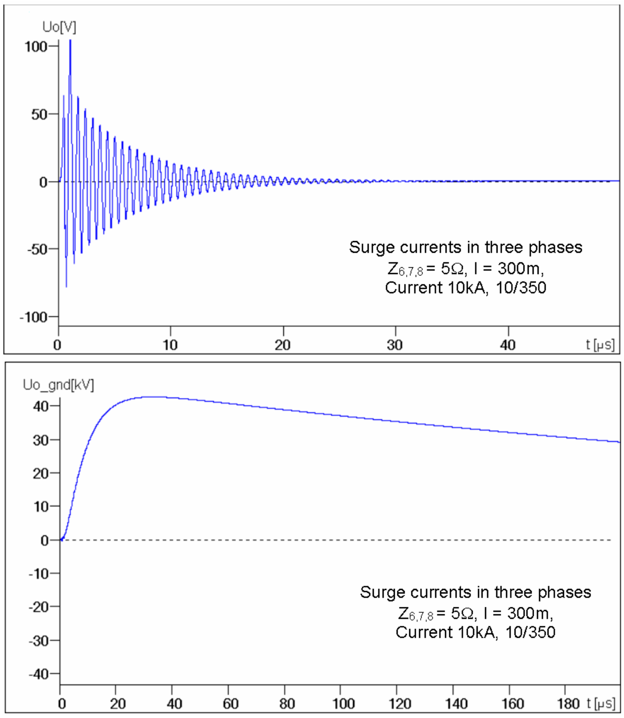

Fig.6. Lightning overvoltages on the loads and potential difference between the phase conductors and true earth.

The potential differences between phase wires L1, L2, L3 and true earth are cause by lightning currents, which flowed through the MV arresters to the grounding system. At the LV side of transformer, the neutral conductor is connected to this grounding system and the voltages on this system are transferred to LV installation.

Inside building, in the worst cases, these potential differences exceed 40 kV.

2.2 Model with LV surge protective devices

In the second part of calculation, the consumer installation was protected by surge protective devices, which were presented as non-linear elements.

SPDs 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.

V-I curve, which was used for representing the characteristics of LV metal-oxide surge arresters, shows Fig.7.

Typical model of MV/LV distribution systems and circuit diagram used for simulate behavior of MV and LV arresters MV/LV system shows Fig.8.

In investigation, we take into account more than 20 different arrangements in MV/LV electric systems.

Some results of calculations are presented in Fig.9 and 10.

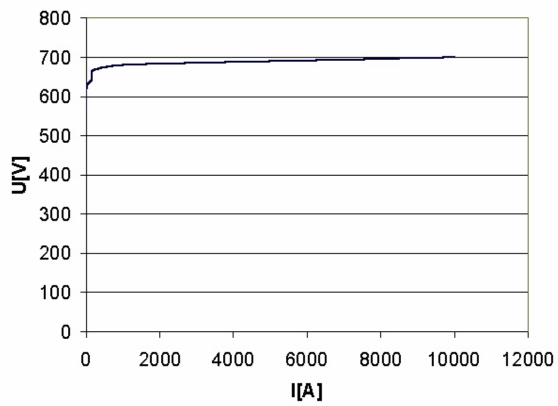

Fig.7. Nonlinear V-I characteristics of typical SPD

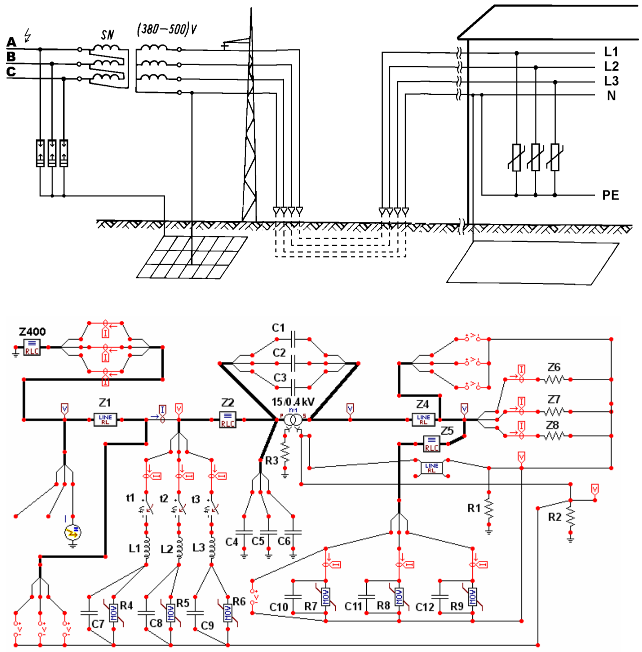

Fig.8. Typical model of MV/LV distribution systems with SPD in LV installation and circuit diagram for calculation

3. CONCLUSIONS

For the purpose of theoretical study a typical models of MV/LV electric systems have been examined. The used of these models permit to evaluate the system's behavior during lightning strike to the wires of MV overhead lines. Calculations showed that the overvoltages in MV system are transferred to LV distributed system by "earth coupling". In these cases, the application of MV arresters on the primary side of transformer did not reduce the potential differences in LV installation inside building.

It can be observed that:

- Voltages on the loads reached the values from some hundred V to some kV.
- The SPD reduced only the overvoltages on the load but the potential differences between the load and the

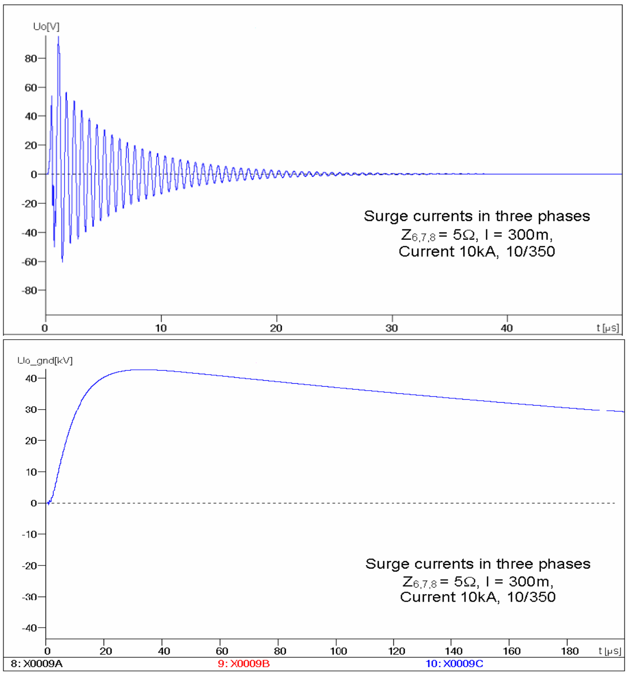

Fig.9. Lightning overvoltages on the loads (R= 5Ω) and between the phase conductors (at load) and true earth.

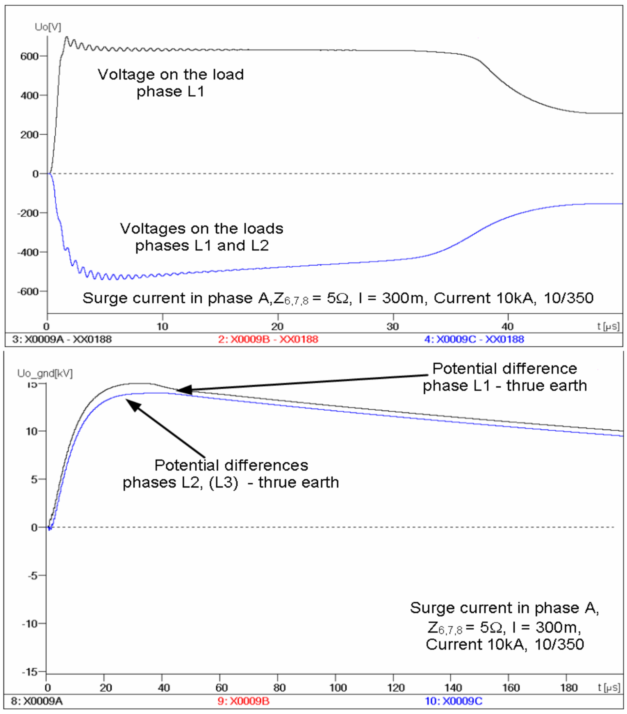

Fig.10. Lightning overvoltages on the loads (R= 5Ω) and between the neutral and true earth.

true earth reach the high values, practically the same like in cases without SPD.

- The potential differences between the wires of LV installation and true earth reached values from some kV to some dozen of kV. In worst cases, the values of these differences (for values of lightning currents which are used in calculation) exceed 40 kV.

These potential differences may be avoided by using different grounding points for MV arresters and the neutral point of transformer's LV side.

This separation is very difficult realized in small power station and in this case it is practically impossible to eliminate this "earth coupling" between MV and LV systems.

In building these potential differences appear between the conductors of installation and another conductive elements which were bounded in another points compared with the bounded bar of electric installation.

This dangerous is eliminated when all conductive services enter the building at the same place and they are bounded to the one main bar or separation transformers are used.

4. REFERENCES

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