Limiting of lightning overvoltages in the electrical Substations 110 kV

Margreta Vasileva[1] Neli Velikova[2] Yordan Ivanov[3] and Danail Stanchev[4]

Abstract – **When a lightning strikes on a power line surges are generated, which are being transferred by it. In the actual circuitry the wave is meeting discontinuities, which are based on various combinations of elements, resulting in occurring processes of multiple refraction and reflection of the wave that alter its shape and amplitude. In the report are presented the results of the model study of lightning stroke on overhead line and its impact on the equipment of a 110 kV substation switchgear including the MOSA.**

Keywords – **metal-oxide surge arrester; lightning protection, high-voltage substation.**

I. Introduction

Electrical equipment in electrical substations (ES) with voltage 110 kV, which are connected to overhead lines are protected from atmospheric surges by metal-oxide surge arresters (MOSA). The MOSA's electrical and mechanical properties must comply with the operational conditions of the switchyard. Surge arresters are placed at the inlet of each power line; each bus system of PS, as well as in front of the power transformers on the supply side. It is also necessary to choose the place of mounting of the surge arresters to make additional calculations related to their selection. [1,2,6].

The aim of the report is to present the results of the model study of lightning stroke on overhead line and its impact on the equipment of a 110 kV substation switchgear and the protective action of MOSA.

In the MATLAB system a simulation model is created of an electric system with six air accessions, which uses real data of substation 110 kV. Through the model is being reviewed the influence of lightning overvoltages on the electrical equipment in the substation. The cases are considered when atmospheric surges enter the substation through the longest power line in normal operation when protected with MOSA and the same case, but without protection equipment. A case of emergency operation of the substation is considered, in which three of its power lines are dropped out.

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II. Model Study of Lightning Protection of 110 kV Substation

A substation is being viewed with six air accessions, namely: "Beton" - 2.51 km; "Avrora" - 13.22 km; "Dobrina" - 14.15 km; "Marciana" - 7 km; "Gigant" - 4.44 km; "Gitnica" - 11.03 km. The substation is whit a single section bus system and has two 110/20 kV power transformers with power 25 MVA. The protection of the facilities is carried out by two metal oxide surge arresters with a protective level U_p = 265 kV, which are being attached to the bus system.

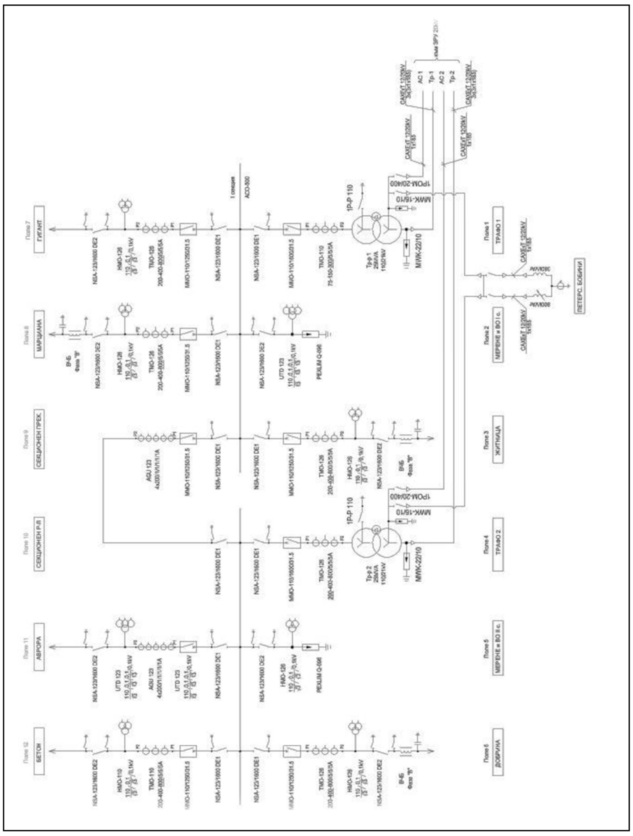

Fig.1 Single-line diagram of the studied 110 kV substatio

The mathematical equations for the definition of the parameters of the substitute circuit of the power transformer (R_T, X_T, z_T, G_T, B_T and others) are described in the literature [4,5].

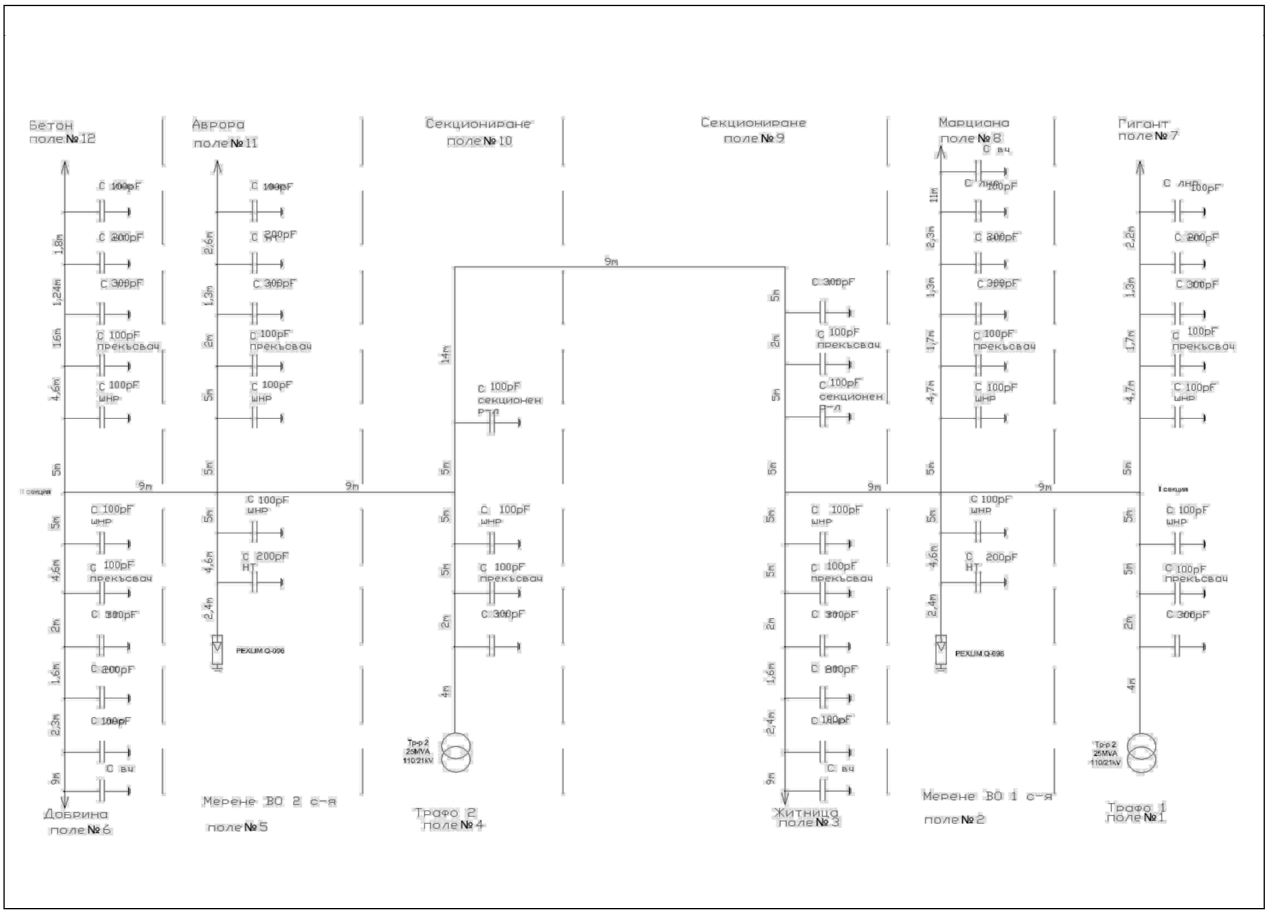

Fig. 2. Equivalent electrical circuit of the 110 kV substation

Fig. 2 is a full replacement scheme of a 110 kV switchyard. It is shows the distance in meters between devices and nodes, and the numbers to the capacitors are the values of their capacity in pF.

Established three-phase model scheme of 110 kV substation in the program MATLAB, in which the equipment is being presented as capacitors with a specific capacitance [3], and power lines and substation buses are modelled by equivalent electrical circuit of line with distributed parameters. Lightning is modelled as a current source with an amplitude of 80 kA and a shape 1/10 μs. The parameters of the replacement schemes are calculated according to [4].

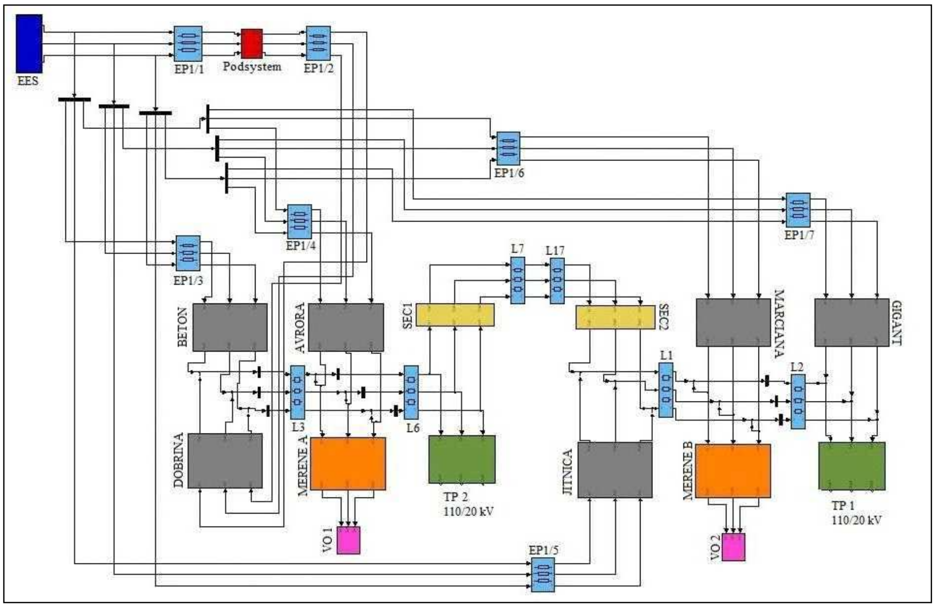

Fig. 3. Simulation model of the Substation 110 kV in a Matlab

III. SIMULATION RESULTS

III.1. Study on impact o a lightning stroke arising in power lines, on the electrical equipment in the substation 110 kV without MOSA

The voltages in the three phases are being controlled - in the place of the lightning stroke and on the power transformers.

A. Damage from lightning on a phase conductor of power line "Dobrina".

The case of a lightning strike in phase B of overhead power line "Dobrina" is being examined. The affected area is on a distance of 100 m away from the substation. The results are shown in fig. 4. and fig. 5.

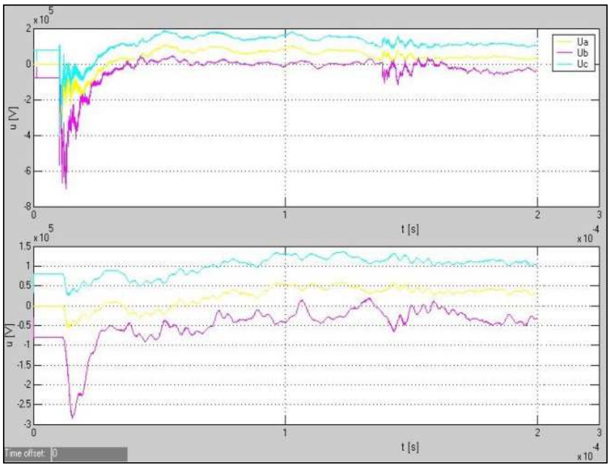

Fig. 4. Voltages in case of lightning stroke on phase B of "Dobrina" without MOSA in the ES (a) the point of the stroke and (b) on the first transformer terminals

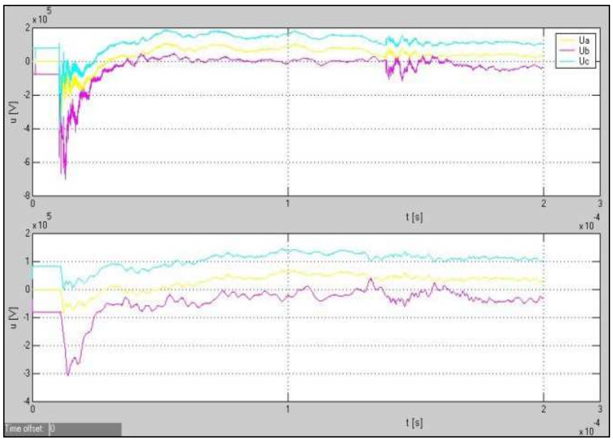

Fig. 5. Voltages in case of lightning stroke on phase B of "Dobrina" without MOSA in the ES (a) the point of the stroke and (b) on the second transformer terminals

B. Damage from lightning on the phase conductor of overhead power line "Beton".

The case of a lightning strike in phase B of the overhead powerline "Beton" is being examined. The affected area is on a distance of 100 m away from the substation. The results are shown in fig. 6. and fig.7.

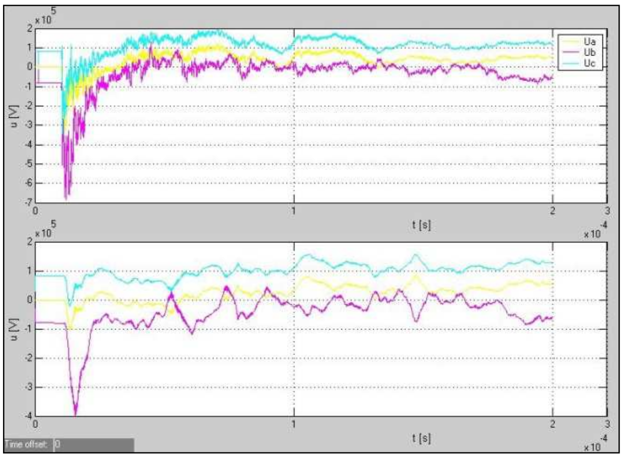

Fig. 6. Voltages in case of lightning stroke on phase B of "Beton" without MOSA in the ES (a) the point of the stroke and (b) on the first transformer terminals

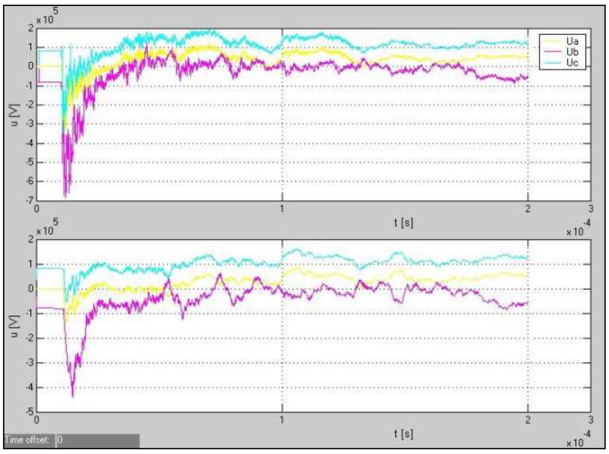

Fig. 7. Voltages in case of lightning stroke on phase B of "Beton" without MOSA in the ES (a) the point of the stroke and (b) on the second transformer terminals

The overvoltages affecting the insulation of the power transformers, if they are not being protected, may exceed their insulation level [5]. It is therefore necessary to be restricted.

III.2. Study on the protective effect of MOSA in case of impact of lightning stroke arising in power lines , on the electrical equipment in the substation 110 kV with MOSA

The situations A and B of p. III.1., are being discussed, but in the case if there is MOSA available in the ES. The results are shown on fig. 8, fig. 9, fig. 10 and fig. 11.

The voltages in the three phases are being controlled - in the place of the lightning stroke, on the power transformers and on the MOSA.

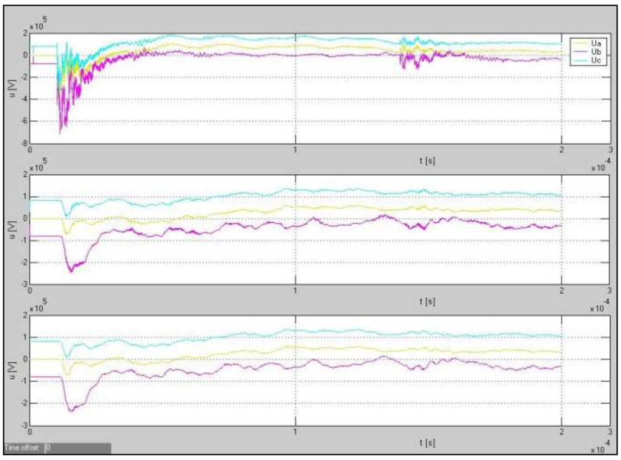

Fig.7. Voltages in case of lightning stroke on phase B of "Dobrina" with MOSA in the ES (a) the point of the stroke; (b) on the first transformer terminals (c) on the surge arrester

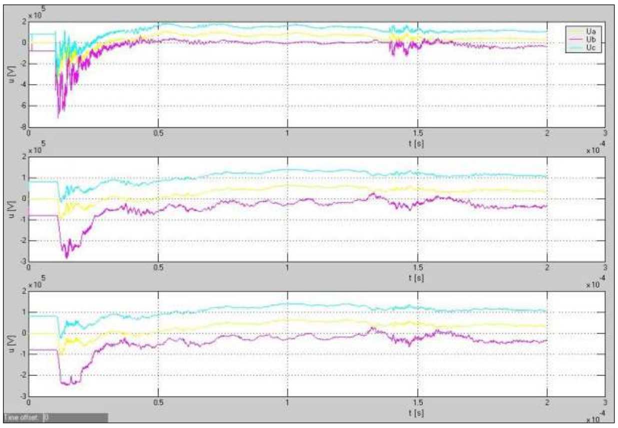

Fig.9. Voltages in case of lightning stroke on phase B of "Dobrina" with MOSA in the ES (a) the point of the stroke; (b) on the second transformer terminals (c) on the surge arrester

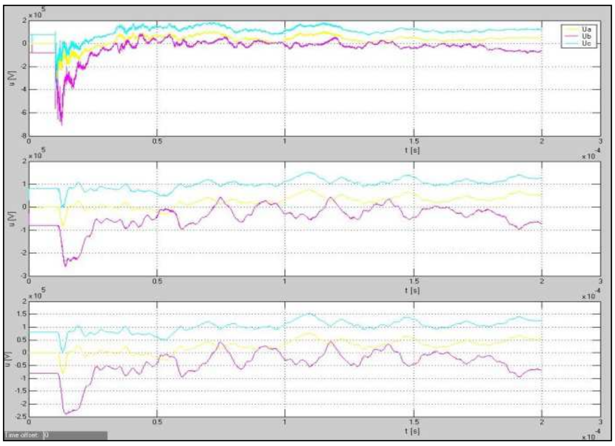

Fig.10. Voltages in case of lightning stroke on phase B of "Beton" with MOSA in the ES (a) the point of the stroke; (b) on the first transformer terminals (c) on the surge arrester

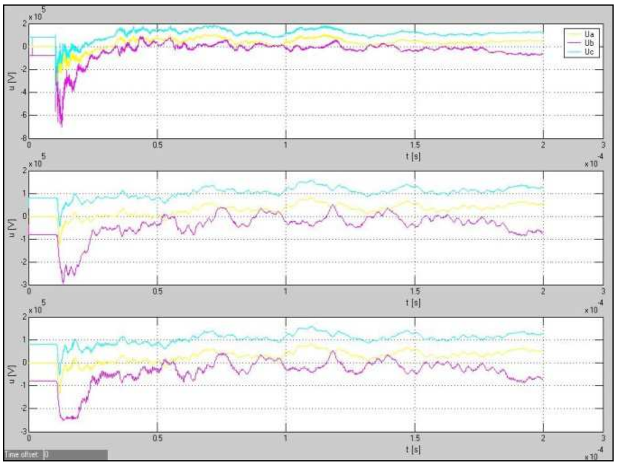

Fig.11. Voltages in case of lightning stroke on phase B of "Beton" with MOSA in the ES (a) the point of the stroke; (b) on the second transformer terminals (c) on the surge arrester

From the results it is apparent, that MOSA can ensure the reliable operation of the equipment and the energy system as a whole. For this purpose it is necessary to make the correct choice of the technical parameters and the place of their installation.

IV. Conclusions

In operation of the substation with six accessions the received surges on the facilities are under their insulation level.

Risk of damage to the equipment in the substation on impact of an atmospheric surge is present in the cases of a smaller number of accessions connected to the bus bar system.

The simulation model of the electric system, presented in the report can be used to study wave processes in electrical substations.

The developed model of the study on the protective effect of metal oxide surge arresters in electrical substation can be used for a more precise choice, taking into account the configuration of the scheme and the participating elements on the effect of the atmospheric overvoltage.

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