Energy Capability of Metal-Oxide Surge Arresters in Electric Power Lines 20 kV

Margreta Vasileva[1] and Marinela Yordanova[2]

Abstract – **Practical experience indicates that the overloading of metal-oxide surge arresters (MOSAs) is due to peak value of lightning current, many consecutive lightning strokes or short-circuits. As a result of this breakdown of resistors occurs or surface discharges. In order MOSAs to be able to operate properly, their energy capability has to be higher than the expected energy loading at the moment of operation. The paper presents research results about protective operation and energy capability of metal-oxide surge arresters (MOSA) under influences of different lighting strokes and thermal loading of MOSA. The models give the emitted in MOSA energy needed to receive the heat field of MOSA.**

Keywords – **zinc-oxide varistor**, **metal-oxide surge arresters, energy capability, thermal replace scheme**

I. Introduction

The energy capability has been connected with the thermal load in the moment, when metal-oxyde surge arresters (MOSA) work. The operation of MOSA has been investigated under the influence of atmospheric excess voltages. An adiabatic thermal process has been considered. The absorption energy from MOSA has been received by mathematical model in Matlab.

The paper presents research results about protective operation and energy capability of metal-oxide surge arresters (MOSA) under influences of different lighting strokes and thermal loading of MOSA.

The researched problems have been resolved by electrical- thermal analogy. The received results are based on the substitute scheme with thermal capacitances, thermal strengthes and thermal fluxes.

The differential equations have been resolved by the method of the potential knots.

II. Models of Lightning and Induced Surge Waves

The shape of lightning and induced surge waves is aperiodic. The created model of lightning is shown in Fig. 1.

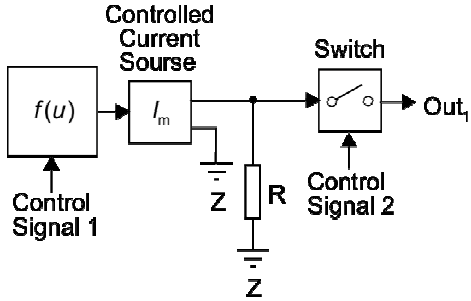

Fig. 1 Block lightning

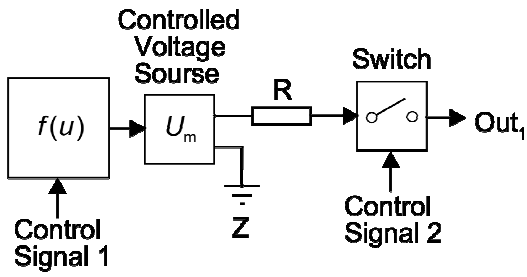

Fig. 2 Block induced overvoltages

The model in Fig. 1 is for single lightning. When there are N numbers of discharges the model consists of N number of that block.

The induced waves are modeled as a source of voltage with arbitrary shape and amplitude- Fig. 2.

Simulation Model of 20 kV grid is presented in [1]. It can be used to study wave processes.

The investigation has been done using the method of trapezoids for solving of the differential equations system. The program ode23t is used.

III. Investigation of the Influence of the Lightning Current Amplitude on the Behavior of MOVO

The processes under examination are connected with operation of the MOSA in electrical power line 20 kV under single lightning stroke over a phase in the first interpole distance of line. The lightning stroke is with amplitude value of the current I_M and shape 1/10 μs.

[1]Margreta Vasileva is with Technical University of Varna, Department of Electric Power Engineering, Studentska 1, Varna, 9010, Bulgaria, m.vasileva@tu-varna.bg
[2]Marinela Yordanova is with Technical University of Varna, Department of Electric Power Engineering, Studentska 1, Varna, 9010, Bulgaria, mary_2000@abv.bg

Fig. 3 illustrates the results for the impact of the lightning current 130 kA (Pprobability of occurrence of lightning with this current is 1 %), and Fig. 4 - for I_M= 20 kA (probability of occurrence - 75 %) [1].

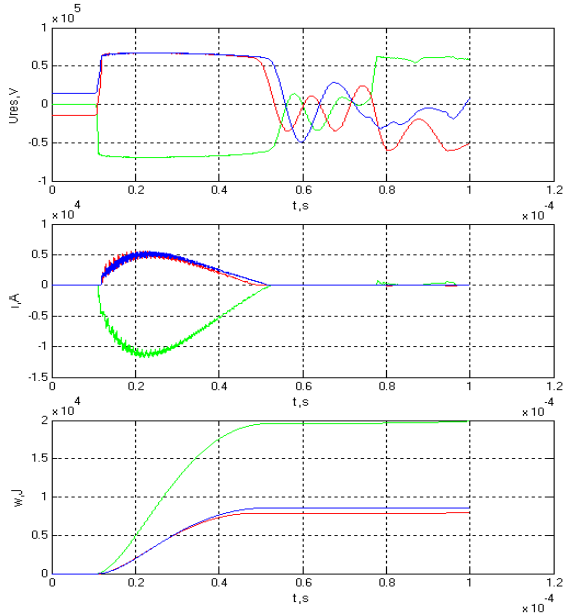

Fig. 3 Residual voltages, currents and energy, emitted in MOSA at I_M =130 kA

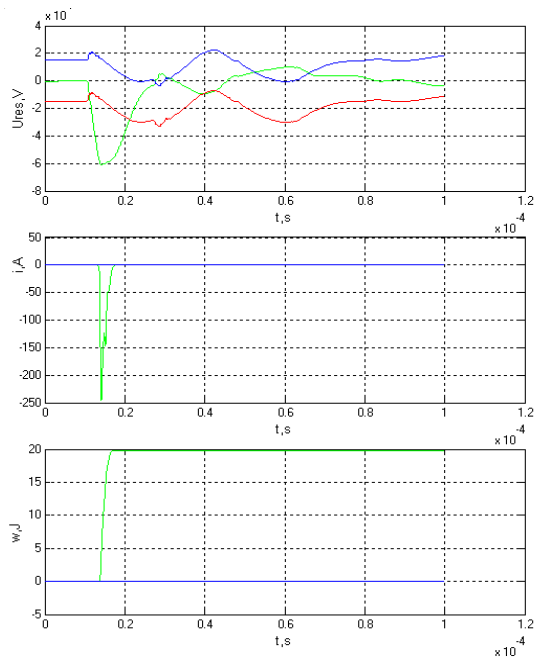

Fig. 4 Residual voltages, currents and energy, emitted in MOSA at I_M =20 kA

IV. Investigation of the Operation of MOSA under Influence of the Lightning Stroke with Two Consecutive Discharges and Induced Overvoltages

The research is done for the same electrical power line 20 kV under lightning stroke with first discharge current amplitude 80 kA and the second - 40 kA. The pause between them is 80 μs.

Residual voltages, currents in MOSA and energy, emitted in MOSA are shown in fig. 5.

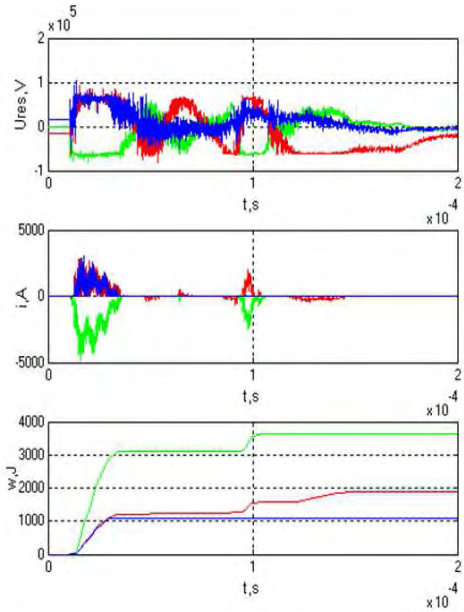

Fig. 5 Residual voltages , currents and energy, emitted in MOSA at double lightning

Fig. 6 and fig. 7 show the results in case of induced overvoltages for power line 20 kV whit amplitude 900 kV and 200 kV. Induced overvoltages with this amplitudes in Power line-20 kV occurred respectively 0,1 and 7 times per year for 30 hours lightning activity per year.

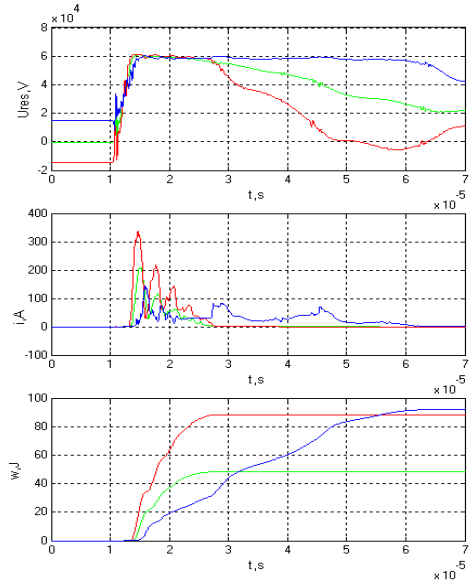

Fig. 6 Residual voltages , currents and energy, emitted in MOSA at induced overvoltages whit amplitude 200 kV

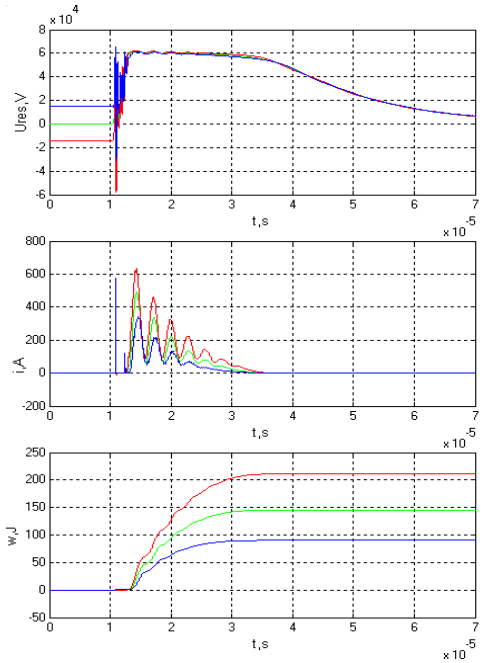

Fig. 7 Residual voltages , currents and energy, emitted in MOSA at induced overvoltages whit amplitude 900 kV

The analysis of the results shows that MOSAs limit overvoltages up to their protection level and retain energy sustainability.

Developed models for studying the behavior of MOVO in the grid can be used for their choice, taking into account the configuration of the system and its participating elements at different shape and duration of surges. They are also used for the next research – thermal loading of MOSA. The models give the emitted in MOSA energy needed to receive the heat field of MOSA.

V. INVESTIGATION OF THE THERMAL LOADING OF THE MOSA AT THE OPERATION MODE

The thermal replace scheme in fig. 8 used electrical-thermal analogy for theoretical research over the heat loading. An adiabatic thermal process has been considered. The absorption energy from MOSA has been received by mathematical model in program Matlab [2],[3]. The differential equations have been resolved by the node potential method.

The following cases are investigated:

- Normal operation in electric power line 20 kV, $I=1.10^{-4}$ A. For the case the heat transfer to the ambient air is taken into account and the ambient temperature is $T_0=45^o$ C.
- Fault situation – one phase short-circuit and transient overvoltage $U=\sqrt{2}.24$ kV, I=0.0015 A ,t = 10 s.
- Single lightning stroke 130 kA, 1/10 µs
- Single lightning stroke 100 kA, 10/350 µs;
- Double lightning stroke 1/10 µs, 80 kA and 40kA with the pause 80 µs;
- Single lightning stroke 4/10 µs, 100 kA – testing case.

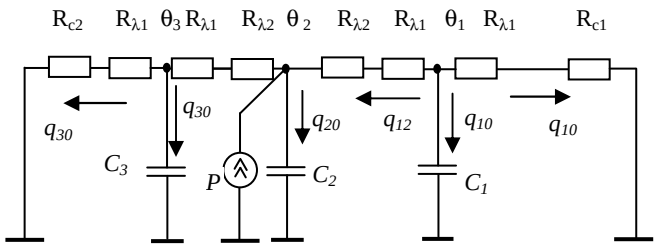

Fig. 8 Thermal replace scheme

R_{c1}, R_{c2}- heat resistance of convection., Rλ2, W/m.K – heat conduction resistance of MOSA; $R_{\lambda 1}$, W/m.K – heat conduction resistance of silicone rubber housing ; C_2 ,J/K – heat capacity of MOSA; C_1 ,C_3, J/K – heat capacity of silicone rubber housing; θ_1, θ_2, θ_3, K- temperature change according to the ambient temperature; q_{ij}, W- thermal fluxes [4], [5].

MOSA is type MWK 24 with: height H=320 mm and diameter d=47 mm and number of blocks n=4. The housing is from silicone rubber.

The results for the temperature change in the work process are shown in Fig. 9 to Fig. 11.

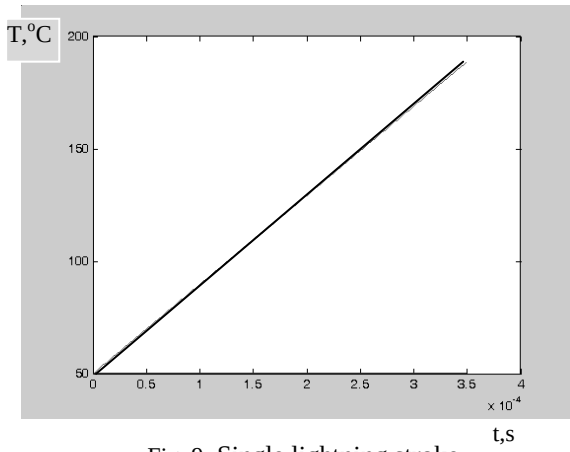

Fig. 9 Single lightning stroke 100 kA, 10/350 µs

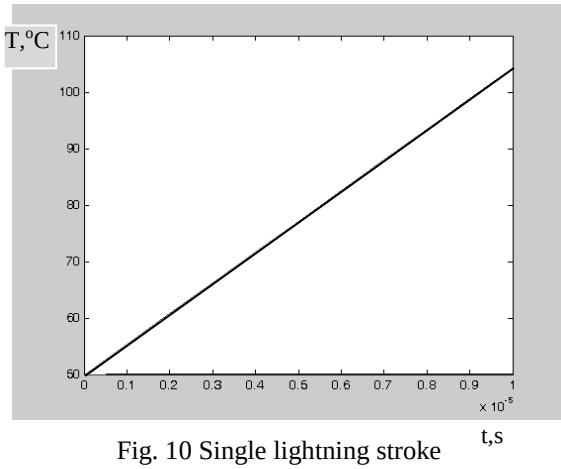

Fig. 10 Single lightning stroke 4/10 µs, 100 kA

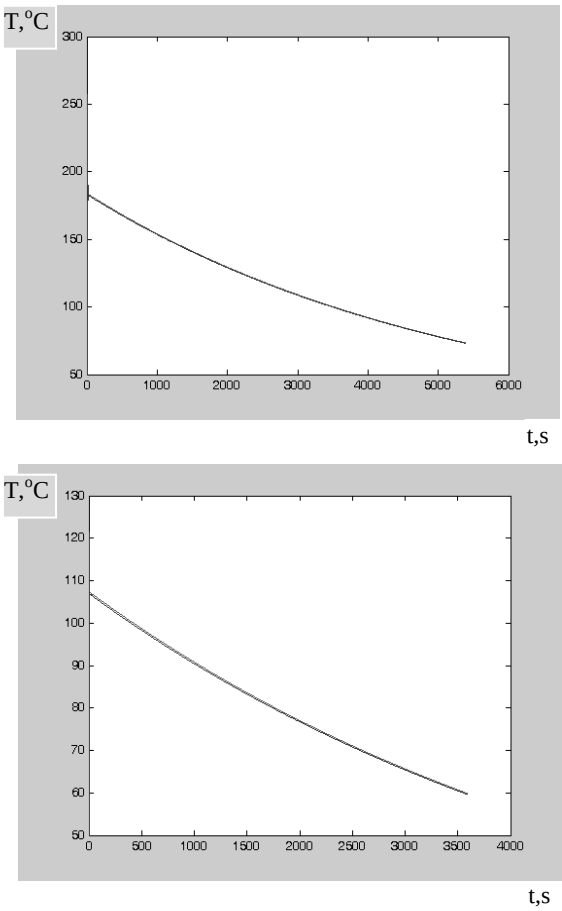

Fig. 11 Cooling below the operating voltage after MOVO's operation

VI. Conclusion

The analysis of the results shows that MOSAs limit overvoltages up to their protection level and retain energy sustainability.

Metal oxide blocks overheating during normal operation of the power line 20 kV is about 5 K, which indicates favorable thermal load conditions.

Acknowledgement

The carried out research is realized in the frames of the project**,** financed from the state budget **"**Investigation of processes in secondary circuits for control and protection**"** in TU-Varna.

In cases of transient overvoltage, single lightning stroke 80 kA, 1/10 μs, double lightning stroke 1/10 μs, 80 kA, 40kA with the pause 80 μs temperatures are established in the range of 51 to 54 ^{0}C for the most adverse environmental conditions - 45 ^{0}C.

Most severe in terms of thermal load are conditions obtained by the influence of lightning off 100 kA, 10/350 μs (Fig. 9) and 4/10 μs, 100 kA (Fig. 10). MOVO temperatures reach values close to the limiting of material.

It is necessary up to 60-90 minutes to receive cooling of MOSAs under rate voltage for the most severe case of thermal loading. If there is another lightning stroke during the cooling process the destruction of MOSAs will happen

The proper choice of MOSAs according to energy loading ensures favorable thermal conditions. The most severe thermal modes are with the least probability, but destruction probability is very high.

References

[1] Vassileva M., Limitting of overvoltages in electrical power networks 20 kV, Technical university of Varna, Bulgaria, PhD Thesis, 2004.

[2] Yordanova M., M. Vassileva, Research over energy capability of metal-oxyde surge arresters in electric power lines 20 kV, Energy forum 2006, Varna, Bulgaria, pp. 114-118.

[3] Petit A., D. Xuan, Jean G, An experimental method to determine the elektro-thermal model parameters of metal oxide surge arresters, IEEE Transactions on Power Delivery, vol.6,№ 2, April 1991.pp. 715-721.

[4] http://www.zinc.org/info/zinc_oxide_properties

[5] http://lib.semi.ac.cn:8080/tsh/dzzy/wsqk/selected%20papers/HIGH%20TEMPERATURE/41-778.pdf