# Enabling More Energy Capacity of the Metal Oxide Surge Arrestors

Margreta Vasileva[1] and Marinela Yordanova[2]
[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

***ABSTRACT:*** *The reasons for lightning strokes in circuits are mainly due to the overloading of metal-oxide surge arrestors. This process leads to the resistors-breakdown in surface discharges. Thus, the requirement in this stage to ensure more energy capacity which should be more than the energy loading. We in this work studied the protective operation and energy capacity of the metal-oxide surge arrestors. The impact of different lighting strokes and thermal loading are considered in this work. The result of this study is the creation of new systems the more production of energy required.*

**Keywords:** Zinc-oxide Varistor, Metal-oxide Surge Arresters, Energy Capability, Thermal Replace Scheme

**Received:** 18 October 2022, Revised 9 December 2022, Accepted 18 December 2022

**DOI:** 10.6025/jism/2023/13/1/1-9

## 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.

## 2. 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 Figure 1.

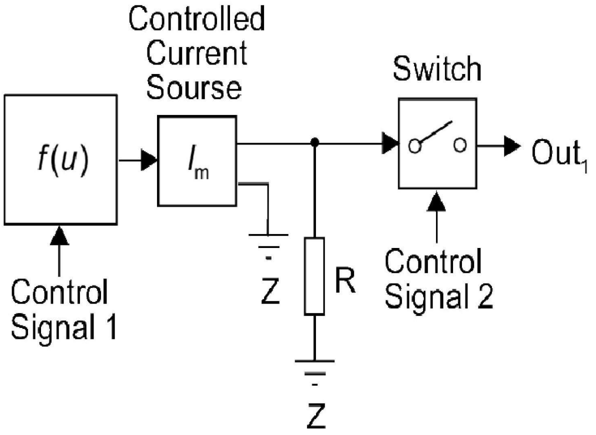


Figure 1 Block lightning

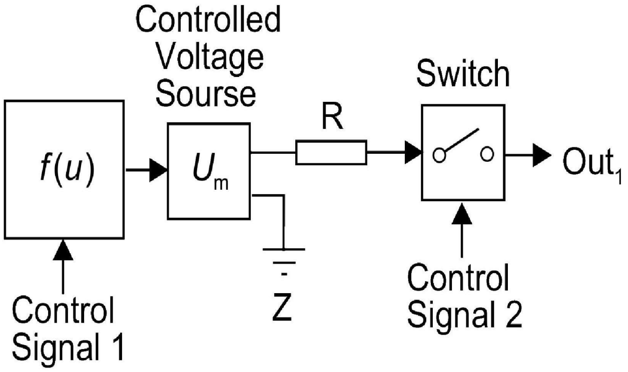


Figure 2. Block induced overvoltages

The model in Figure 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- Figure 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.

## 3. 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 IM and shape 1/10 μs.

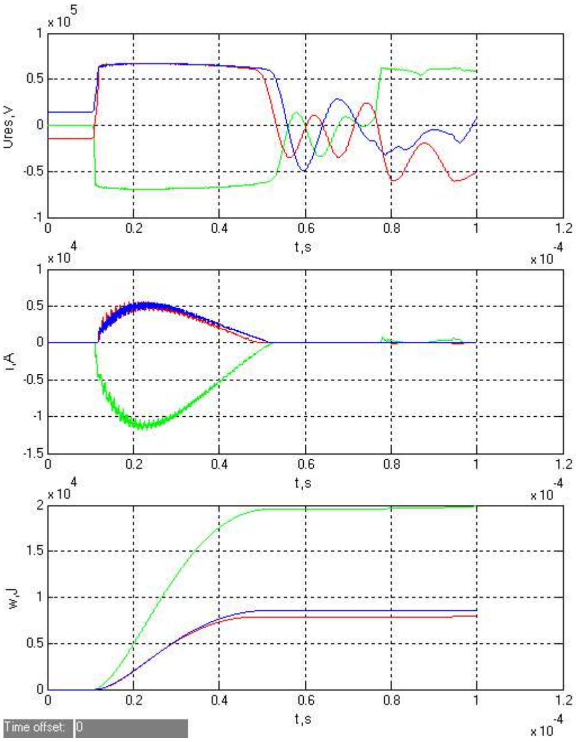


Figure 3. illustrates the results for the impact of the lightning current 130 kA (Pprobability of occurrence of lightning with this current is 1 %), and Fig. 4 - for $I_M$= 20 kA (probability of occurrence - 75 %) [1]

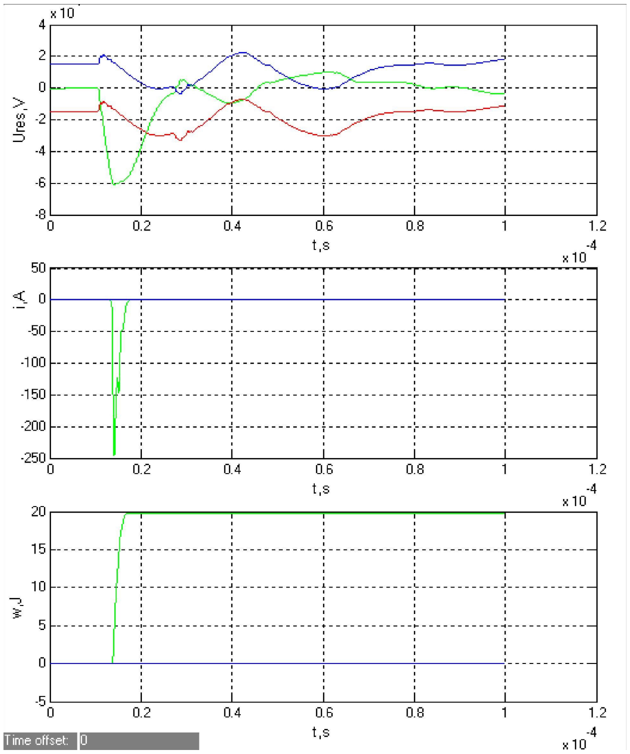


Figure 4. Residual voltages, currents and energy, emitted in MOSA at *I*< =20 k

## 4. 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 k? 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 figure 5.

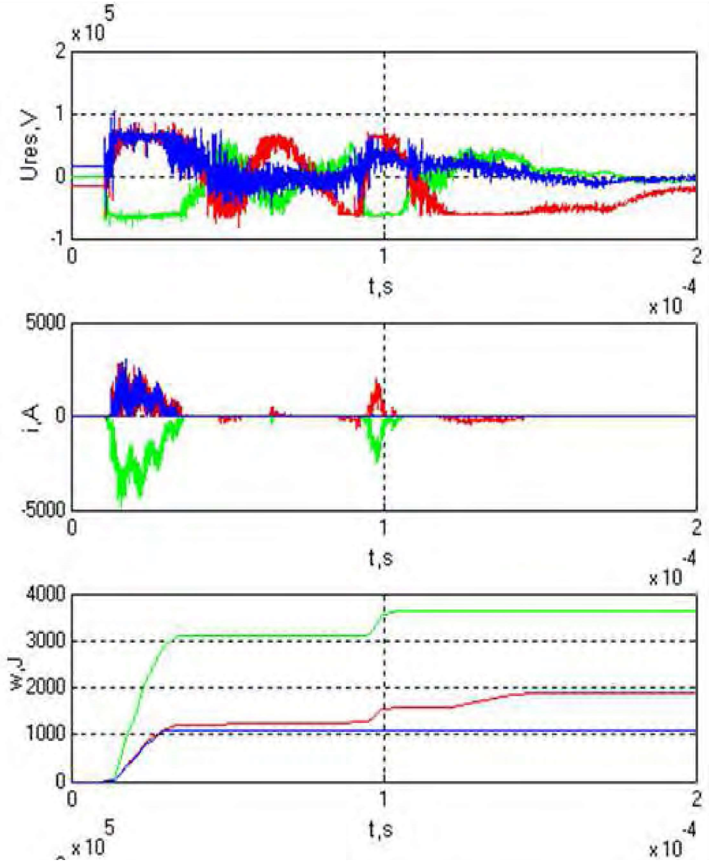


Figure 5. Residual voltages , currents and energy, emitted in MOSA at double lightning

Figure 6 and figure 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.

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.

## 5. Investigation of the thermal Loading of Themosa 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

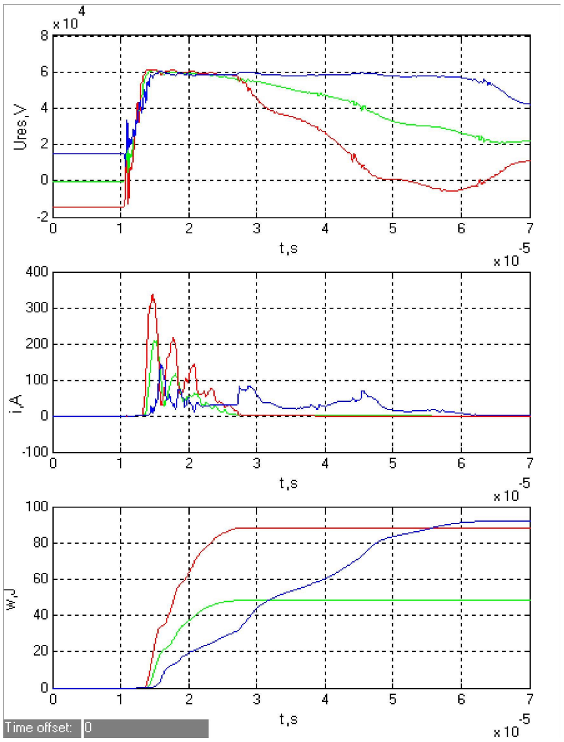


Figure 6. Residual voltages , currents and energy, emitted in MOSA at induced overvoltages whit amplitude 200 kV

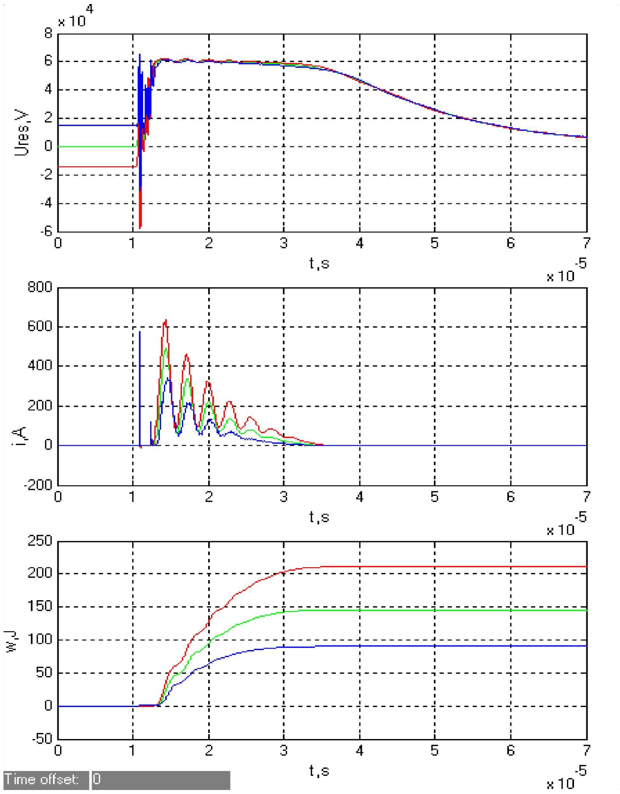


Figure 7. Residual voltages , currents and energy, emitted in MOSA at induced overvoltages whit amplitude 900 kV

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 $T_0 = 45^{\circ}$ 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.

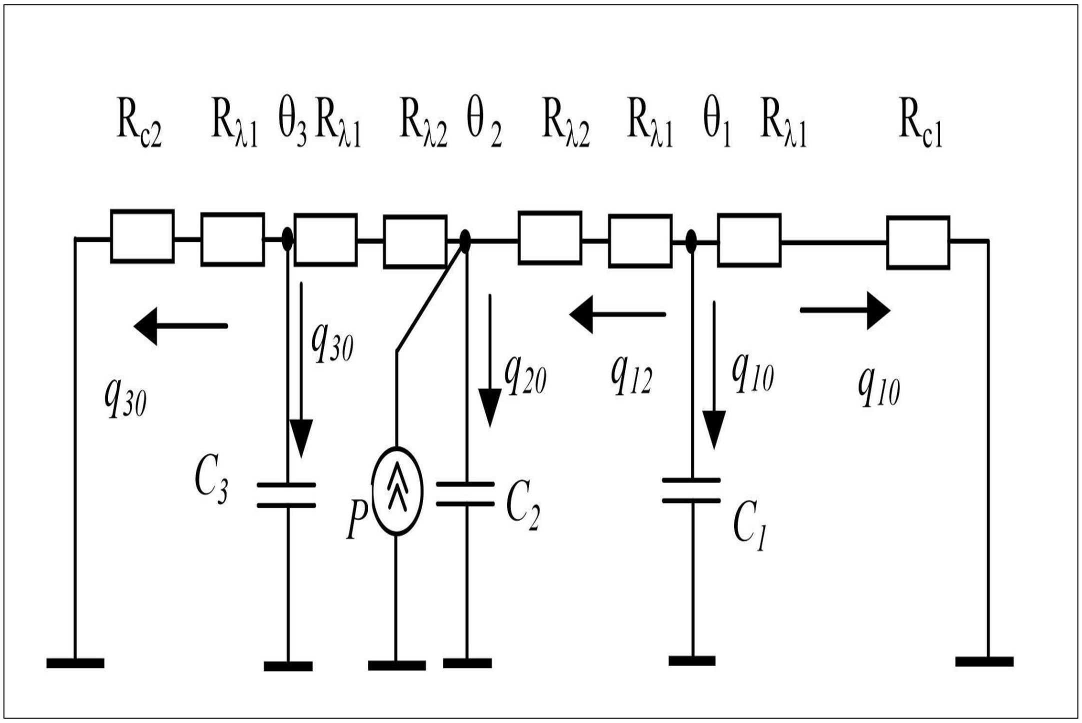


Figure 8. Thermal replace scheme

$R_{c1}$, $R_{c2}$- heat resistance of convection., $R_{\lambda 2}$, *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; $\theta_1$, $\theta_2$, $\theta_3$, *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 Figure 9 to Figure 11.

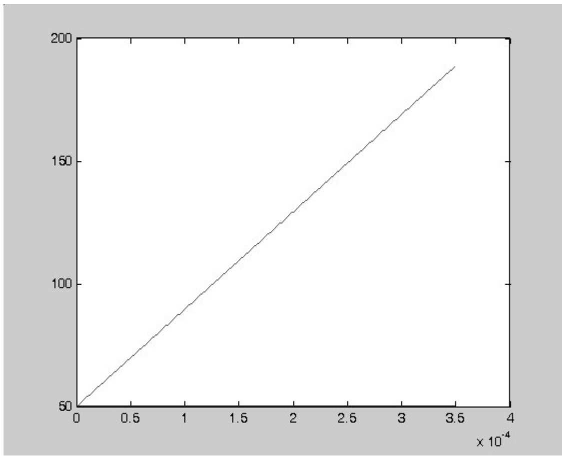


Figure 9. Single lightning stroke 100 kA, 10/350 μs

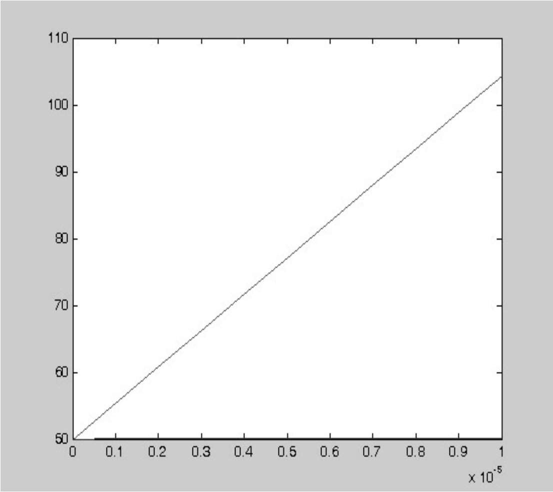
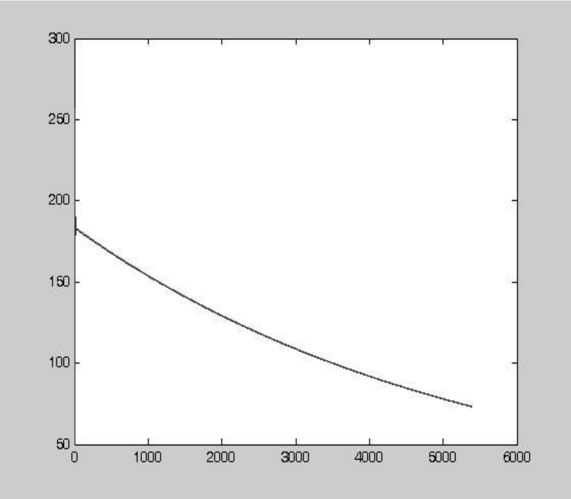


Figure 10. Single lightning stroke 4/10 μs, 100 kA



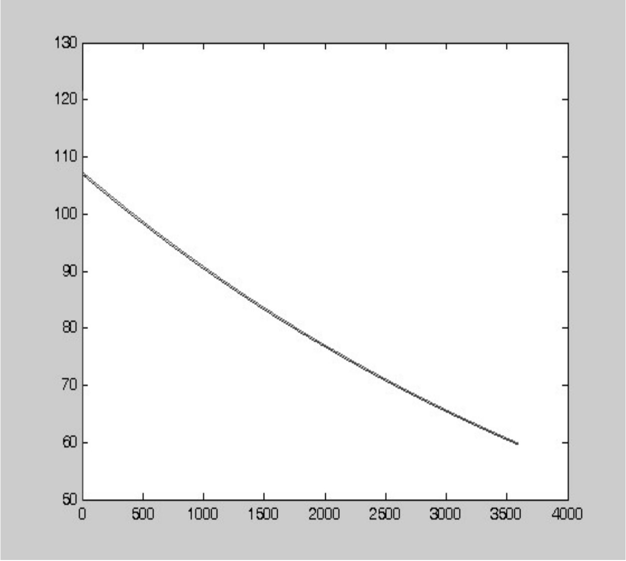


Figure 11. Cooling below the operating voltage after MOVO's operation

## 6. 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 (Figgure 9) and 4/10 ms, 100 kA (Figure 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.

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