ISSN 1392 – 1215 *ELECTRONICS AND ELECTRICAL ENGINEERING* 2010. No. 10(106)
ELEKTRONIKA IR ELEKTROTECHNIKA

T 190 *ELECTRICAL ENGINEERING*
ELEKTROS INŽINERIJA

Electric and Magnetic Field at the HV Substation during Lightning Strike

R. Markowska, A. Sowa, J. Wiater
Department of Telecommunications and Electronic Equipment, Bialystok University of Technology, ul. Wiejska 45d, 15-351 Białystok, Poland, phone: +48 85 7469444, e-mail: jaroslawwiater@we.pb.edu.pl

Introduction

In typical high voltage substation are present electronic devices such as: devices for overcurrent, distance, ground-fault protection. They are very sensitive for any transient state especially for transients caused by lightning strike. Disoperation one of the crucial HV substation or HV overhead transmission line can cause a blackout. Circuit breakers are situated at the key points of electrical energy transmission and distribution systems. Their reliability has a decisive influence on the availability, safety and economic efficiency of electrical supply networks. Although most electronic equipment has some limitations exist on the maximum voltage and shape of the transient voltages that can be lead-in. Electronic components and equipment can have an immediate failure when subject to voltages larger than their maximum rated values.

Transient voltages can also alter the characteristics of an electronic component without any immediate sign of damage. Unless there is a way to determine transient voltages, such anomalies can remain undetected and eventually lead to a premature and unexpected failure of a component.

Transient voltages or currents can be measured or calculated for lightning conditions. Electric and magnetic field approximation is more complicated. There is no such easy method as for example digital oscilloscope to record transient electric or magnetic field in the air without any results disturbances. Electric and magnetic field determines inducted voltages and currents in HV circuits, so knowing it level could be useful to naturally prevent high transient voltages levels by changing devices agreement. Additionally, there should be noticed that impulse electric and magnetic field directly interact on electronic devices and electronic systems.

Analyzed HV substation

Polish high voltage substations are projected and made according the structural design called KSU-3.

All modifications concern required devices localization for the specific relief. For calculation purposes mathematical model was performed according the original substation documentation [1, 2]. All steel conductors were buried at 0.8 m depth in homogeneous soil.

Mathematical modeling and simulations were performed by HIFREQ software, which is a part of CDEGS package [4]. The model includes a grounding network as well as simplified models of aboveground elements such as metallic construction and bonding network.

Quick view on the HV substation model is presented in figure 1.

Detailed modeling procedure and mathematical model with respect to the technical data and measurements results were presented in the author's previously publicized paper [5]. In quick overview analyzed and modeled HV substation consists of:

- single busbar design with the busbar being split into sections and interconnected via a bus section circuit-breaker;
- two incoming circuits – one feeding each section of busbar and two outgoing circuits feeding multi-radial networks for overhead rural systems and ring circuits for urban cable connected networks;
- two distribution substation transformers 110/15 kV 6% 16 MVA;
- grounding system consists of steel conductors with cross section 80 mm^2;
- steel conductors were buried at 0.8 m depth in homogeneous soil (resistivity 100 Ωm and relative permittivity ε_r =1).

Lightning current flow in the HV substation is strictly correlated with the source type used for this purpose. Generally in presented calculations lighting stroke model will be represented as current source with selected shape at an arbitrary height 22 m along the lightning channel and by LEAD source implemented in HIFREQ software.

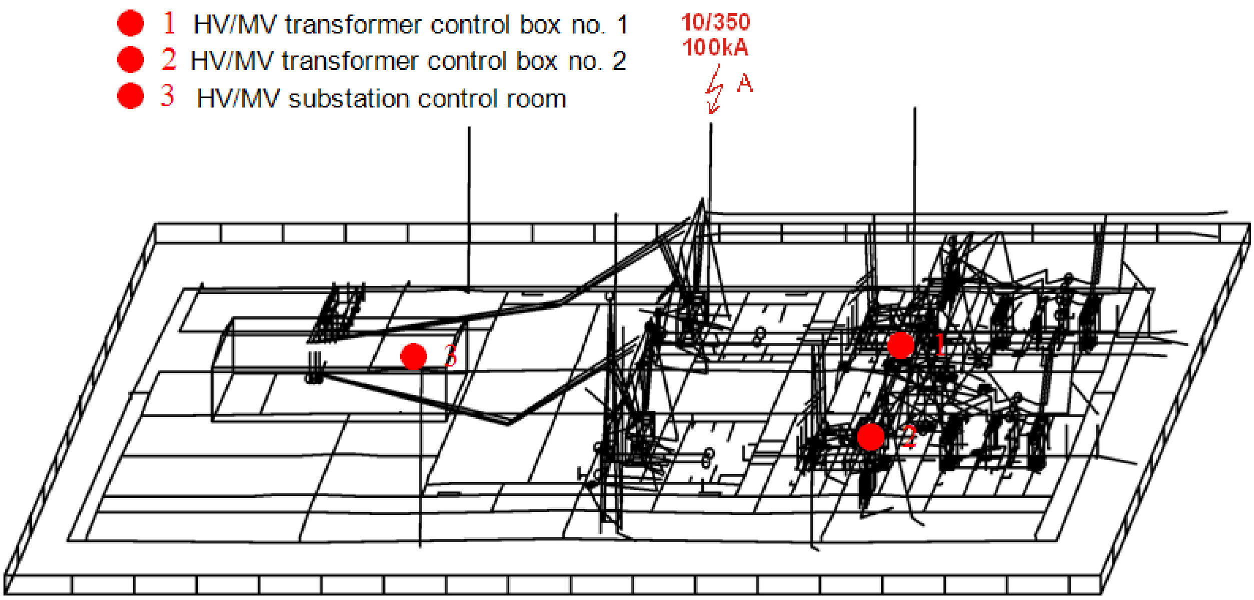

Fig. 1. Simplified graphical representation of the HV substation mathematical model – 3D View [5]

In analysis, the surge current 100 kA (peak values) and shape 10/350 μs was used for simulation the first lightning stroke.

This lightning current was described by typical equation

$$i = \frac{I}{\eta} \cdot \frac{(t/\tau_1)^{10}}{1 + (t/\tau_1)^{10}} \cdot e^{-\frac{t}{\tau_2}}, \quad (1)$$

here I is the peak current 100 kA; $\eta = 0.930$ correction factor for the peak current; t is the time; $\tau_1 = 19$ μs front time constant; $\tau_2 = 485$ μs tail time constants.

Lightning source were connected to the HV substation model in A point presented also on Fig. 1.

The LEAD energization is used to specify the current to be injected into the network. Analyzed substation model consist of 2014 segments which are representing analyzed object. With the LEAD energize, a current of ReI + j ImI is forced to flow into the origin of the energized conductor towards its end [4].

The computation methodology assumes frequency decomposition of the time domain current surge [4], frequency domain computations for a single harmonic unit current energize and superposition of the frequency domain computations modulated by the amplitude of the lightning current [8-10].

Calculation results

According to provided simulation Fig. 2 - 7 presents electric and magnetic field calculations results in time domain for selected points during direct lightning strike on HV substation area:

- nearby HV/MV transformer No. 1 control box,
- nearby HV/MV transformer No. 2 control box,
- in HV/MV substation control room.

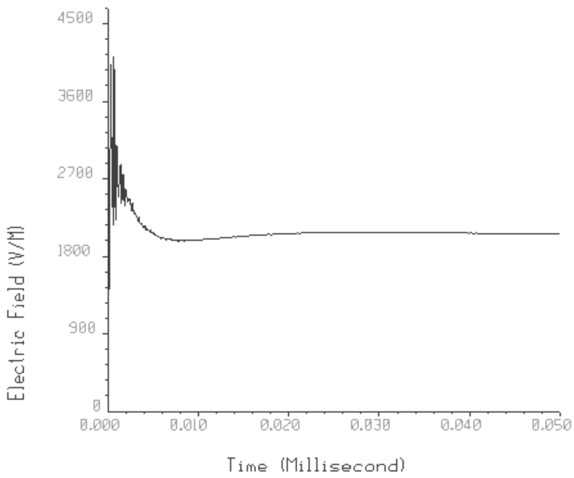

Fig. 2. Electric field nearby HV/MV transformer No. 1 control box at 0.01 m height

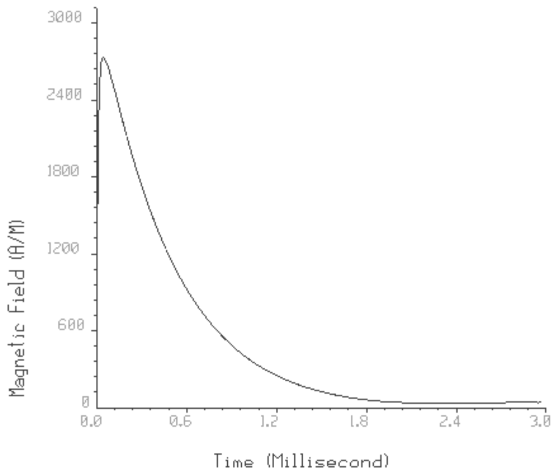

Fig. 3. Magnetic field at 0.01 m height nearby HV/MV transformer No. 1 control box

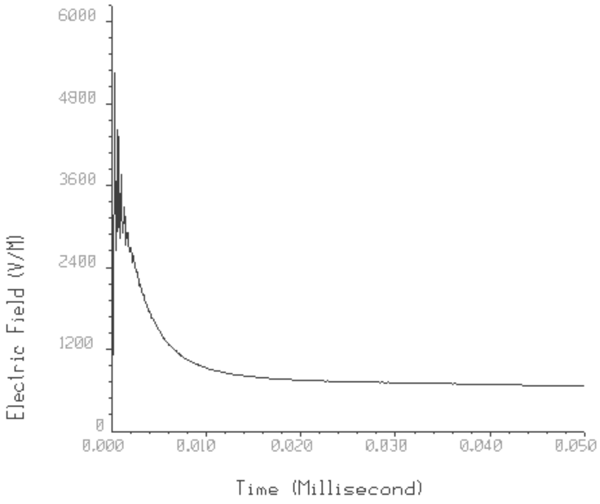

Fig. 4. Electric at 0.01 m height nearby HV/MV transformer No. 2 control box

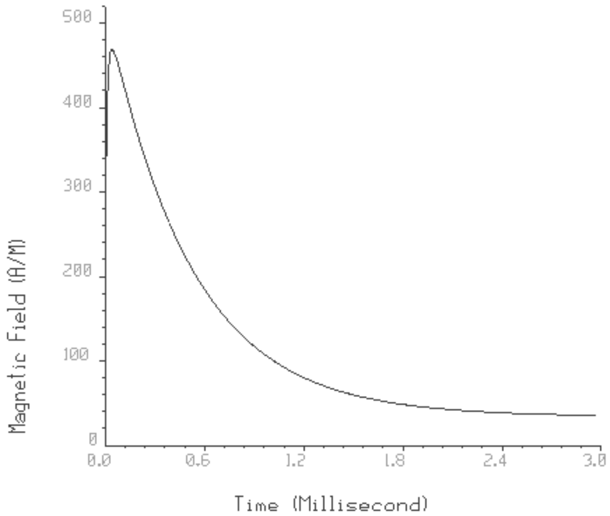

Fig. 5. Magnetic field at 0.01 m height nearby HV/MV transformer No. 2 control box

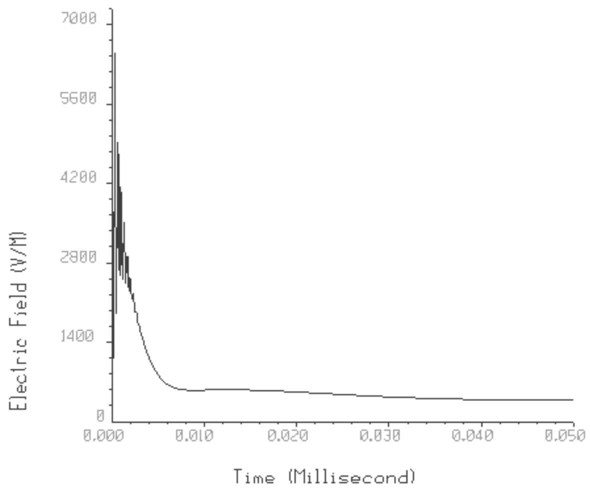

Fig. 6. Electric field at 0.01 m height in HV/MV substation control room

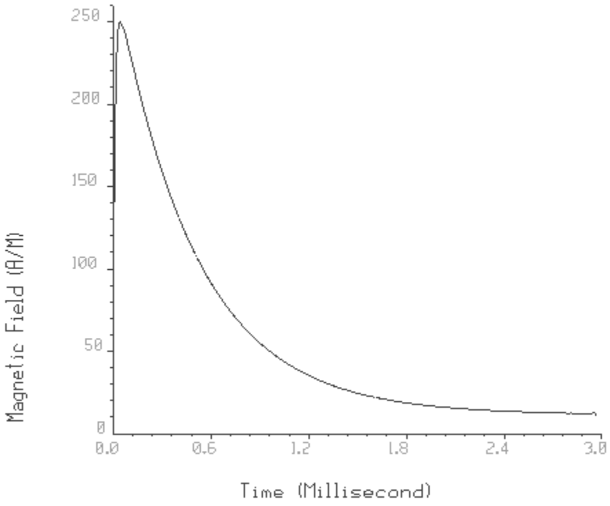

Fig. 7. Magnetic field at 0.01 m height in HV/MV substation control room

Calculation results shows that highest electric and magnetic field is observed nearby other metallic parts which HV/MV substation is build off.

Curve of electric field have got oscillations which probably are produced by travelling voltage wave in grounding system [5].

Conclusions

A numerical procedure, based on the fields approach, has been proposed to calculate the field strength caused by lightning stroke into open area HV/MV substation.

The values of electric and magnetic fields reached 6 kV/m and 3.7 kA/m adequately.

For detailed lightning hazard approximation it is necessary to continue calculations with proposed method. For specific electric and electronic devices used in substation it is necessary to made additional calculation with specially prepared model with high number of details located nearby.

Obtained results correspond to other received inside the building [7].

References

1. Energoprojekt Kraków S. A. The HV Voltage Substation Technical Data – type KSU–3/ 110/15kV.
2. Energoprojekt Kraków S. A. Measuremets data for calculations for HV substation (110/15 kV).
3. PN–E–05115. Power installations exceeding 1 kV a.c. – 78 p.
4. Ses Software Canada, HIFREQ Theory. – P.7–12
5. **Wiater J.** Lightning hazard approximation of the control devices located in the electric power substations (PhD thesis). – Bialystok Technical University, Bialystok, 2009 (in Polish).
6. IEC 62305–1. Protection against lightning. – Part 1: General principles.
7. **Miyazaki S., Ishii M.** Induced Magnetic Field Inside of Directly Stricken Building by Lightning, 28th International Conference on Lightning Protection. – Kanazawa, 2006.
8. **Grainys A., Novickij J.** The Investigation of 3D Magnetic Field Distribution in Multilayer Coils // Electronics and Electrical engineering. – Kaunas: Technologija, 2010. – No. 7(013). – P. 9–12.

9. **Boudiaf A.** Numerical Magnetic Field Computation in a Unilateral Linear Asynchronous Motor without Inverse Magnetic Circuit // Electronics and Electrical Engineering – Kaunas: Technologija. – 2009. No. 2(90). – P. 81–84.

10. **Bartkevičius S., Novickij J.** The Investigation of Magnetic Field Distribution of Dual Coil Pulsed Magnet // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 4(92). – P. 23–26.

Received 2010 10 22

R. Markowska, A. Sowa, J. Wiater. Electric and Magnetic Field at the HV Substation during Lightning Strike // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 10(106). – P. 79–82.

This paper examines the electric and magnetic fields in an outdoor electric power substation 110/15 kV during lightning strike. The results of calculation were presented in time domain. Transient voltages can be easily measured or calculated for lightning conditions. Electric and magnetic field approximation is more complicated. There is no such easy method as for example digital oscilloscope to record transient electric or magnetic field in the air without any results disturbances. Electric and magnetic field determines inducted voltages and currents in HV circuits, so knowing it level could be useful to naturally prevent high transient voltages levels by changing devices agreement. Ill. 7, bibl. 10 (in English; abstracts in English and Lithuanian).

R. Markowska, A. Sowa, J. Wiater. Elektrinis ir magnetinis laukas žaibo išlydžio metu aukštosios įtampos pastotėje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 79–82.

Šiame straipsnyje publikuojami 110/15 kV pastotėje žaibo srovės sukurtų elektrinio ir magnetinio laukų tyrimai. Skaičiavimai atlikti laiko masteliu. Žaibo srovės indukuotos įtampos gali būti išmatuotos arba apskaičiuotos, tačiau elektrinio ir magnetinio laukų dydžių reikšmes įvertinti sunkiau. Elektrinio ir magnetinio laukų matavimo tikslumui įtakos turi parinktas matavimo metodas. Žaibo išlydžio srovės sukurti elektrinis ir magnetinis laukai pastotėje indukuoja įtampas ir sroves elektros įrenginiuose. Elektros įrenginių darbo sąlygas galima įvertinti žinant pereinamojo vyksmo elektrinio ir magnetinio laukų vertes. Il. 7, bibl. 10 (anglų kalba; santraukos anglų ir lietuvių k.).

DOI: 10.5755/j02.eie.9123