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Lightning transients in the control and supervision systems on the HV substation

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Abstract – **Electronic devices incorrect operations caused by lightning transients has been observed on the HV substation. This concerns specially the digital devices used in high voltage measuring and controlling techniques. This paper presents a calculation results lightning transients in the control and supervision devices signal inputs during direct lightning strike to the HV substation.**

I. Introduction

In view of the growing number of factors with a disturbing influence on power systems and the ever increasing sensitivity of the devices and installations on the HV substation LV side, simple monitoring criteria such as undervoltage or overcurrent are usually inadequate nowadays. In typical high voltage substation are present electronic devices such as: devices for example overcurrent, distance, ground-fault protection. They are very sensitive for any transient state. As it is well know lightning strike could generate it. 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 maximum duration 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 is present, such anomalies can remain undetected and eventually lead to a premature and unexpected failure of a component.

Transient voltage recorders have been used for many years to monitor voltage spikes in cables. Common sources of transient voltages include large electric motors, switching of power equipment, induced voltages from nearby lightning, and direct lightning strikes. The transients generated by sources other than lightning tend to have frequency components well below 1 MHz, which most commercial transient recorders can detect and record. On the other hand, lightning-induced transients contain voltage peaks with amplitudes that rise from 10 to 90 percent in a fraction of a microsecond and can generate multiple transients within a few milliseconds of each other. Special protection methods to prevent lightning damage are simple, very reliable, and inexpensive, particularly when compared to the cost of equipment repair and replacement. However, methods for lightning special protection cannot be found without scientific researches. Lightning transients in the control and supervision systems on the HV substation will be presented below.

II. Analyzed HV Substation

Polish high voltage substations are projected and made according the structural design called KSU-3 [1,2]. All modifications concern required devices localization for the specific relief. Analyzed HV substation consists of:

• single busbar design with the busbar being split into to 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% 16MVA,
• grounding system consists of steel conductors with cross section 80mm2.
• steel conductors were buried at 0,8m depth in homogeneous soil (restivisty of first layer 165.3243 Ω·m with thickness 0.1033122m, second one 394.7320 Ω·m with thickness 0.2303869m, last one 204.3552 Ω·m with infinity thickness, relative permittivity ε_r=1).

For calculation purposes mathematical model was performed according the original substation documentation [1,2]. All steel conductors, with cross section 80 mm^2, were buried at 0,8 m depth in homogeneous soil (for one and two layer ground model). Numerical simulations were performed by MultiFields software package, which is a part of CDEGS package [4]. The numerical model includes an earthing network as well as simplified models of aboveground elements such as flag pole structure and bonding network. Quick view on the HV substation 3D model shows figure 1.

The computation methodology assumes frequency decomposition of the time domain current surge [4], frequency domain computations for a single harmonic unit current energization and superposition of the frequency domain computations modulated by the amplitude of the lightning current – shape 10/350μs, peak value 100kA [4].

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

where:

I – peak current, η – correction factor for the peak current
t – time, τ_1 and τ_2 respectively front and tail time constants.

In the case of theoretical model, the lightning current represents ideal current source which was connected to A point on the HV substation area (fig. 1). Localization of the control and supervision data lines present figure 2.

cables can reach up to +/-300kV. After 2μs observed oscillations disappear. Figure no. 4 presents a voltages for time window up to 50μs. This part of the calculated waveform show influence of control devise placement for the voltage level. Those voltages are determined by the galvanic coupling of the various control devices interconnected each other. Calculated voltage level is different for each selected devices input/output. Received calculation results oscillate from +14kV to -17kV (fig. 4). After 50μs calculated voltages are almost equal (fig.5). They values oscillate from +1kV to -1kV and after 2ms they fade to zero.

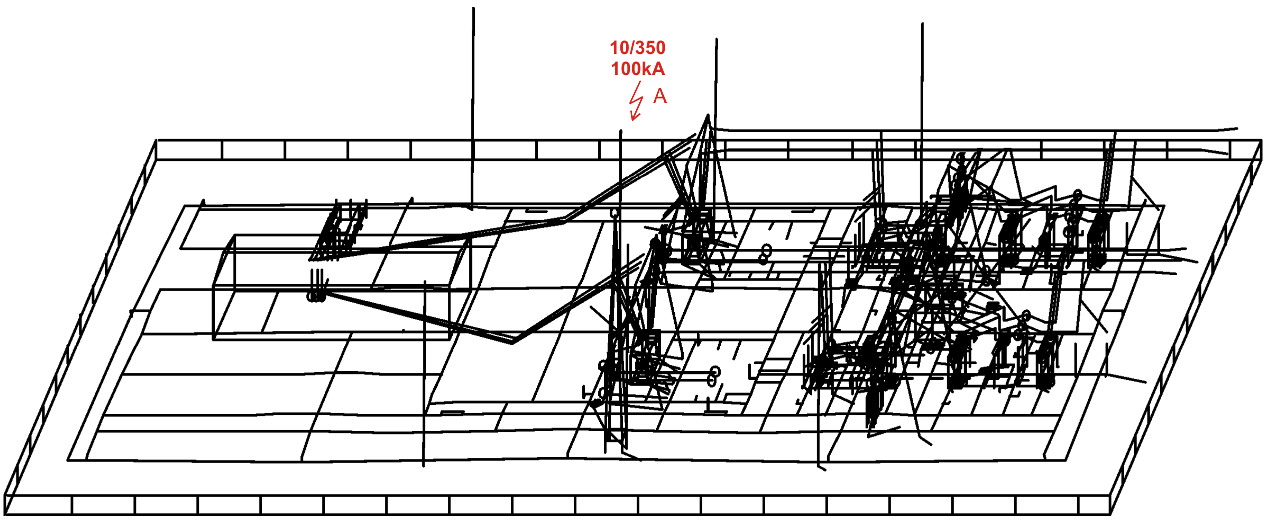

Figure 1. Tree-dimensional HV substation model built in CDEGS software

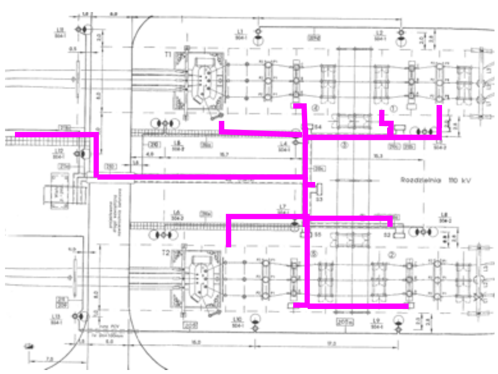

Figure 2. Localization of the control and supervision data lines

III. SIMULATION RESULTS

Figures 3 to 5 present calculated voltages on selected inputs/outputs of the control and supervision system. Detailed description of them shows table no. 1. For clear view it is necessary to split received results on three figures. Each one present selected time frame. For time from 0 to 2μs calculated voltages represent a travelling and back voltage wave reflected form each end of the HV substation (fig. 3). Voltage on the

TABLE I
DESIGNATION OF THE CONTROL AND SUPERVISION LINES

1	HV switch driving signal for the HV/MV transformer no. 2 control field – OU2Z signal
2	HV switch driving signal for the HV/MV transformer no. 2 control field – OU2S signal
3	Position signal of the circuit breaker – line field no. 1
4	Voltage measuring transformer output – phase L1, HV/MV transformer no. 2 control field
5	HV switch driving signal for the HV/MV transformer no. 1 control field – OU2Z signal
6	HV switch driving signal for the HV/MV transformer no. 1 control field – OU2S signal
7	Position signal of the circuit breaker – line field no. 2
8	HV circuit breaker driving signal for the HV/MV transformer no. 2 control field – ZW signal
9	HV circuit breaker driving signal for the HV/MV transformer no. 1 control field – ZW signal
10	Position signal of the circuit breaker – HV/MV transformer no. 1 control field
11	HV circuit breaker driving signal in the busbar link section – ZW signal
12	Equipotent busbar in the 15kV switching-station – field no. 1 fixed contact

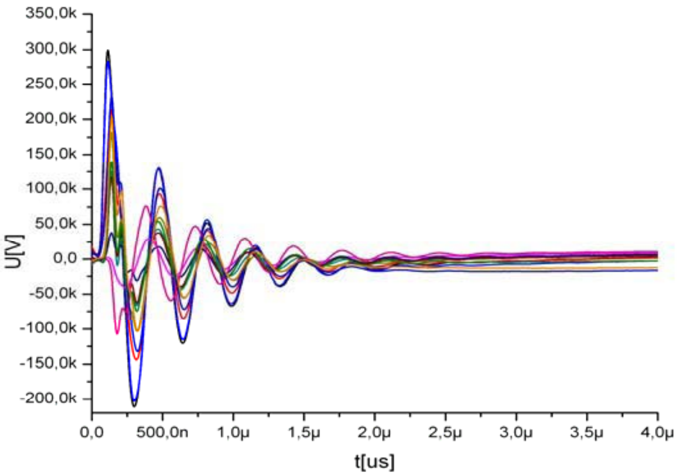

Figure 3. Calculated voltage on the control and supervision lines

(t∈<0;4>µs, 100kA, 10/350µs)

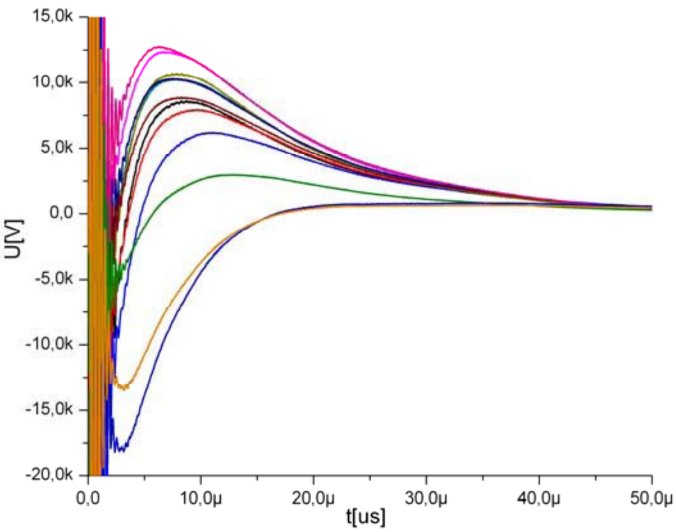

Figure 4. Calculated voltage on the control and supervision lines
(t∈<0;50>µs, U∈<-20;15> kV, 100kA, 10/350µs)

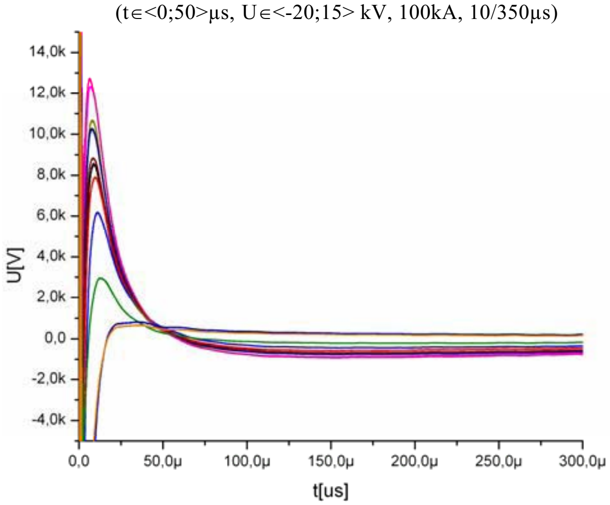

Figure 5. Calculated voltage on the control and supervision lines
(t∈<0;300>µs, U∈<-5;15> kV, 100kA, 10/350µs)

Figure.6 presents ground potential rise on the HV substation measuring area (transformer no. 1 control field) for specified time t=2µs. The two microsecond moment in time corresponds maximal voltage on control devices inputs/outputs.

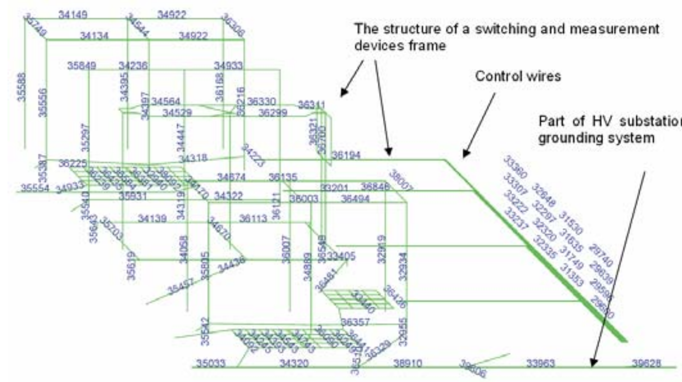

Figure 6. Ground potential rise on the HV substation measuring area - transformer no. 1 control field (t=2µs, 100kA, 10/350µs)

IV. Conclusions

Direct lightning strike to the earthed components of HV substation can cause severe interference problems in electronic equipment and systems. In article, a method for computer analysis of GPR (Ground Potential Rise) in the HV substations was presented. The advantages of the proposal calculation are the following:

- all possible configurations of conductive elements on the HV substation and different points of lightning stoke to the substation's area can be represented in theoretical model,
- impulse voltages and currents in cables under the grounds can be analyzed.

For the lightning hazard of the control and supervision devices installed on the HV substation are fundamental first 20 microseconds after lighting stroke. Calculations results show that major hazard for them is ground potential rise.

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