XIX-th International Conference on
Electromagnetic Disturbances

EMD 2009

September 23-25, 2009, Białystok, Poland

INFLUENCE OF DIFFERENT LIGHTNING SOURCE MODELS ON CURRENT DISTRIBUTION IN THE HV SUBSTATION

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Summary: The purpose of this paper is to extend knowledge about current flow on the HV substation during lightning strike for different source models used for calculations. All calculations were made by HIFREQ software. Substation model were created and verified according to real object technical data and measurement results. Differences in calculation results were presented.

Keywords: current flow, substation, lightning, HIFREQ

1. Introduction

The MV/LV substation takes major part in electric power distribution system. High reliability of system requires knowledge about surge propagation in neuralgic points of it. This problem appears simultaneously with growing number of electronic devices which are MV/LV substations equipped. Different current flow in the substation can change voltage distribution with respect to remote ground. Major problem during surge level calculation is proper choose of the lightning source model. Disturbances in substation electronic control devices make danger especially for electric power system stability. Differences in calculation results can be dangerous by over or under estimate surge level. Wrong surge protection can result in substation incorrect work. Under estimation can even provide to damage some very sensitive equipment. In worst case even black-out can appear and make large financial damage.

2. Analyzed HV substation

Polish high voltage substations are projected and made according the structural design called KSU-3. All modifications concern required devices localisation 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 modelling and simulations were performed by HIFREQ software, which is a part of CDEGS package [4]. The model includes an grounding network as well as simplified models of aboveground elements such as metallic construction and bonding network. Quick view on the substation 3D model shows figure 1.

Detailed modelling procedure and mathematical model with respect to the technical data and measurements results were presented in the authors previously publicised paper [5]. In quick overview analyzed and modelled 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 $80mm^2$.
- steel conductors were buried at 0,8m depth in homogeneous soil.

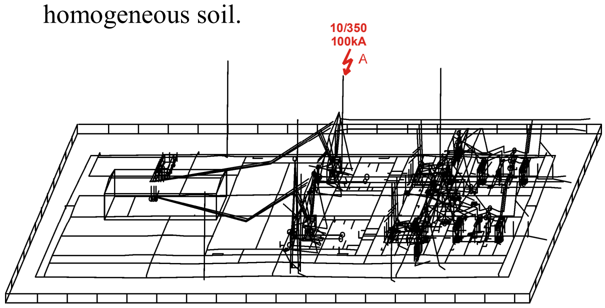

Fig.1. Simplified graphical representation of the HV substation mathematical model – 3D View [5]

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 according the equation 1 at an arbitrary height (tab. 1) along the lightning channel:

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

where:

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

and by LEAD source implemented in HIFREQ software. All sources types were connected to the HV substation model in A point presented also on figure 1. The LEAD energization is used to specify the current to be injected into the network. It can be applied to both pseudo-nodes and proper-nodes while the typical current source can be applied to proper-node only [4]. This limitation provides some differences in calculation results which are going to be presented below. Pseudo-node is a conductor segment endpoint which is not in contact with another conductor segment in the HV substation model, i.e., a point which terminates in the surrounding medium (lightning rod), while a proper-node is a conductor endpoint which is in contact with another conductor segment. Analyzed substation model consist of 2014 segments which are representing analyzed object. With the LEAD energization, a current of *ReI+jImI* is forced to flow into the origin of the energized conductor towards its end [4]. If the origin of the energized conductor is a proper-node, the LEAD energization acts as a current source, familiar from circuit theory. The proper-node energization can be used, for instance, to model a loop with a specified circulating current. If the origin of the energized segment is a pseudo-node, i.e., for this case, the current is assumed to be drawn from an adjacent network which is not modeled, i.e., thunderstorm cloud [4].

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.

Tab.1. Selected for analyze source types and channel length

No.	Channel length	Source type
[-]	[m]	[Lead/Current]
1	22	Lead
2	2000	Lead
3	22	Current
4	2000	Current
5	0	Lead
6	50	Lead
7	0	Current
8	50	Current

3. Calculation results

Current and LEAD sources were connected to the lightning rod with variable height from 0 to 200 meters. Current sources were connected to the bottom of lighting rod. LEAD one to the top of it. For current source it was necessary to connect it at the bottom because reflection of current waveform appeared when it will be connected on the top of lightning rod. Comparison of the calculation results could be possible in this case.

Different lengths on lightning rod were used to simulate different lightning channel. In this way influence of lightning channel length on current flow in the HV substation were investigated.

Changes in current flow were observed in 4 different points presented on figure 2. Calculated current waveforms were presented on figures 3-6. Observed calculation results were similar for main flowing segment representing lightning channel – fig. 3. Red curve (no. 2) represents LEAD source for 2000 meters lighting channel. Current reflection effect doubles a maximal calculated value after time needed to observe waveform on ground level.

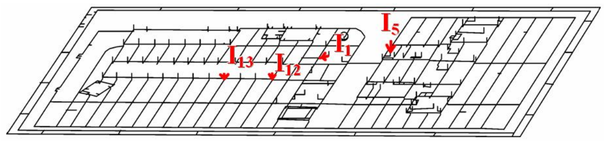

Fig.2. Simplified graphical representation of the HV substation model of the grounding system with observed currents localization [5]

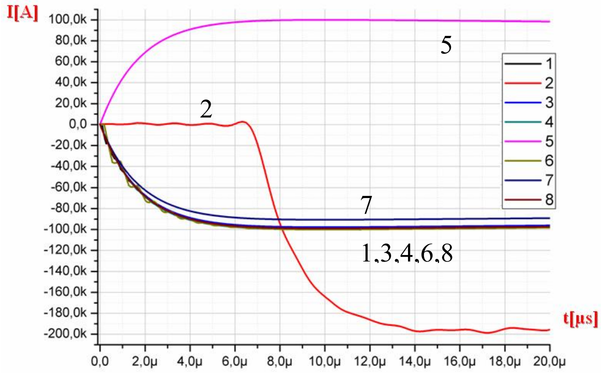

Fig.3. Calculated current (I_1) which is flowing from lightning rod which is representing channel to grounding system for different channel length and source types – 100kA, 10/350 μs

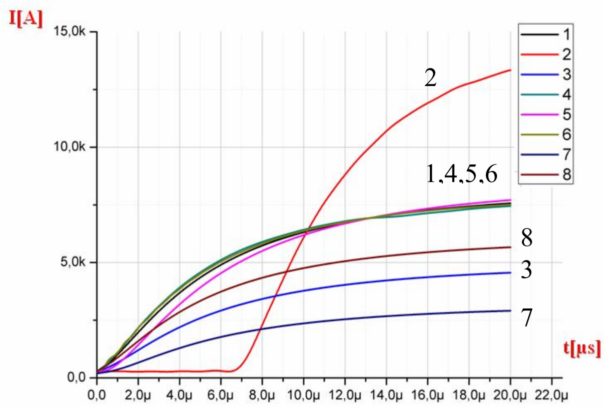

Fig.4. Calculated current (I_{12}) which is flowing from bounding bar of the main control room to main control room grounding system for different channel length and source types – 100kA, 10/350 μs

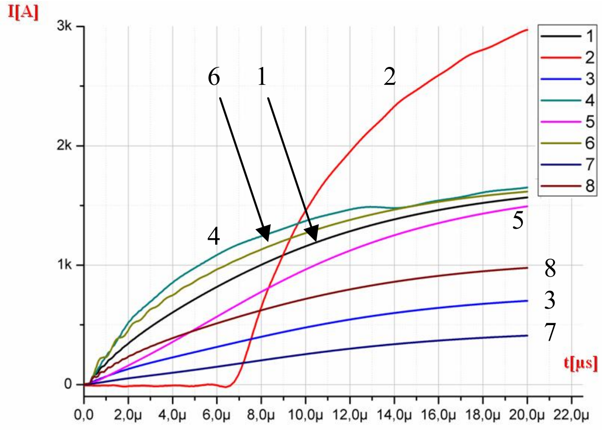

Fig.5. Calculated current (I_{13}) which is flowing from bounding bar of the 15kV control room to main control room grounding system for different channel length and source types – 100kA, 10/350 μs

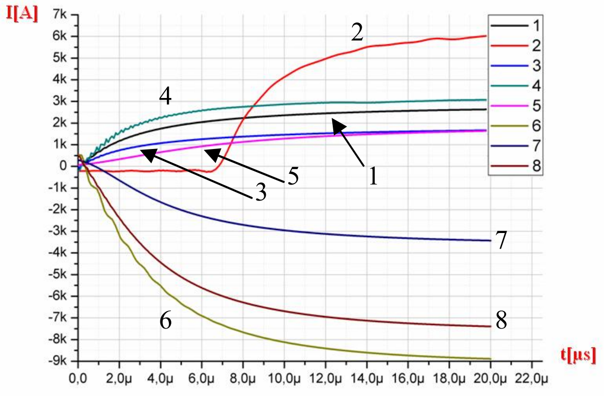

Fig.6. Calculated current (I_5) which is flowing from over ground steel structure carrying 110kV circuit breaker in substation section one to HV substation grounding system for different channel length and source types – 100kA, 10/350 μs

Typical current source initiated biggest error for calculated current (I_{12}) which is flowing from bounding bar of the main control room to main control room grounding system - fig. 4. After time required for wave to travel from channel origin do its end error appears. It is worth to be pointed out that maximal value of calculated current is correlated with error provided by using current source instead LEAD one. When maximal value of current is below 10% of current source used as energization the error is significant high – fig. 5 and 6.

4. Conclusions

Proper choose of surge protection devices is crucial for HV substation control devices lightning hazard. Presented above calculation results can help to choose proper lightning source model to minimize calculation error. Calculations made with LEAD source can be very quick and effective way to minimize error and finally to calculate adequate currents flow in the HV substation. For detailed lightning hazard approximation it is necessary to continue calculations with LEAD source and channel length equal 22 meters. For specific devices used in substation it is necessary made additional calculation with especially prepared model with high number of details located nearby. Provided analyzes proves that created model and method is accurate for calculation of the HV substation lighting current distribution.

5. References

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