OVERVOLTAGES IN PROTECTIVE AND CONTROL CIRCUITS DUE TO SWITCHING TRANSIENTS IN HIGH VOLTAGE SUBSTATION

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Abstract: Switching operations in primary circuits and earthing faults induced very often surge voltages and currents in low-voltage cables in the area of high-voltage HV substation. These transients can cause severe problems in operation of the electric and electronic devices in measurement and control systems.

1. INTRODUCTION

In high voltage HV substation the damages or malfunctions of the electric and electronic equipment or systems very often were caused by switching operations in primary circuits, earthing faults or lightning strokes. In these cases the surge currents flow through the conductive-earthed structures over the ground, by the earthing grids and could induce overvoltages in low-voltage wires.

The problem with these transients has been particularly observed in HV substation with digital devices in control and measurements systems.

The oldest electromechanical elements were very well insulated and required sustained signals to operate.

This is the contrast to microprocessors base equipments. They are more sensitive to overvoltages and overcurrents in control cables.

This paper presents a computer analysis of surge voltages, which were induced in low-voltage cables during switching operations in HV system.

In investigation the influence of cable routing, parameters of earthing systems and location of switching points were taken into account.

2. NUMERICAL MODEL

Mathematical model was employed to determine the induced surge voltages in low-voltage wires during switching operation in HV system. These wires were under the ground located nearby electric and electronic devices in different points of the HV substation's area.

2.1. High-voltage power system

The electric power system being modeled consists of the following components:

- substation S1, where the switching operations took place,
- substation S2 and S3 connected with substation S1,
- overhead transmission lines with grounding wires.

Distances between stations S1 - S2 and S1 – S3 were 3 km (Fig.1.).

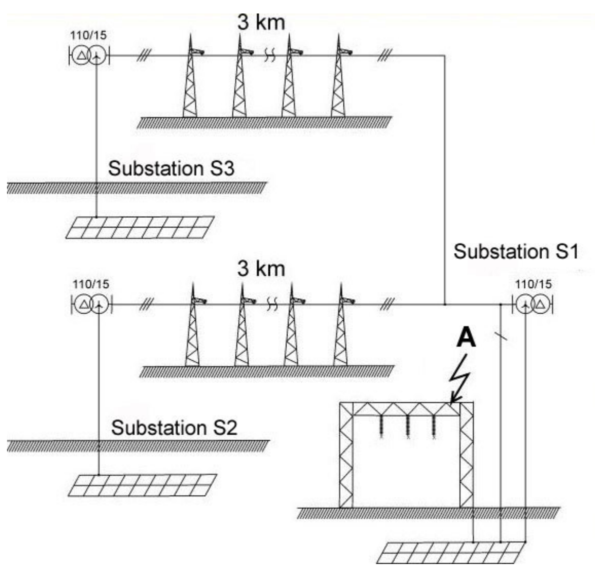

Fig. 1. Electric HV power system

A typical HV substation, which was analysed, 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,

- 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.

On each station were the same arrangements of HV equipment and low-voltage control wires.

The earthing system is considered to be an arbitrary network of connected buried conductors.

The rectangular grid 107m x 62m is made of 6 equal space conductors along the X-axis and 10 along the Y-axis.

Fig.2 illustrates the earthing system adopted for analysis.

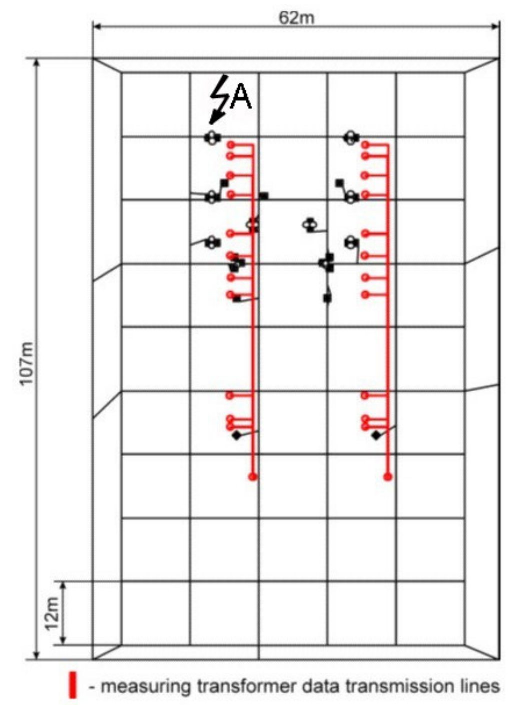

Fig. 2. The substation-earthing grid

All steel conductors, with cross section 80 mm^2, were buried at 0,8 m depth in homogeneous soil (uniform ground model) with:

- resistivity $\rho = 100\ \Omega m$,
- relative permittivity $\varepsilon_r = 1$.

The perimeter of the grid was placed such that the outermost conductors are located exactly 5 m outside the edge of the fence.

The fence is regularly connected to the outermost conductors.

2.2. Low-voltage wires

In HV substation most dangerous are the surges induced in protective and control cables between the electric and electronic equipment located in control building inside the HV substation and other in different points on the substation area (fig. 3.).

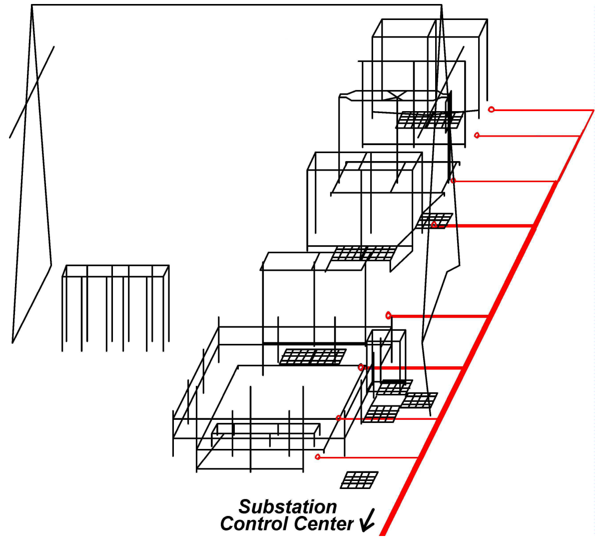

Fig.3. Configurations for computing the surge voltages in signal wires

The calculation was made for the wires with following parameters:

- lengths 62 m,
- distance between layers – 10 mm and between cables in each layer – 10 mm.
- cables run under the ground on 200 mm depth.

The arrangements of control cables in substation S1 are presented in Fig.4. For these wires the surge voltages between:

- different wires ($U_{1\text{-}2}$, $U_{1\text{-}3}$, …),
- wires and local bounding bar ($U_{1\text{-}BB}$, $U_{2\text{-}BB}$,…),
- wires and the true earth ($U_{1\text{-}RE}$, $U_{2\text{-}RE}$, …)

have been computed at the interface of electronic equipment in control building.

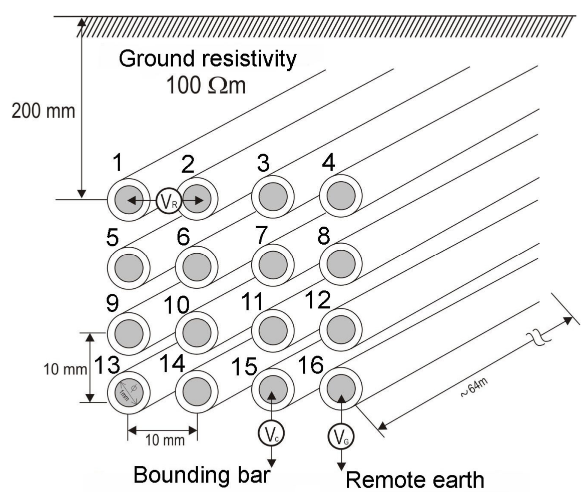

Fig.4. Configurations for computing the surge voltages in signal wires

2.3. Numerical model of substation

The analyses arrangements have been performed by the MultiFields [6,7] software package, which is a part of CDEGS package. The computation methodology assumes the frequency domain analysis, in which each conductor in the network is partitioned in small segments (Fig. 5.).

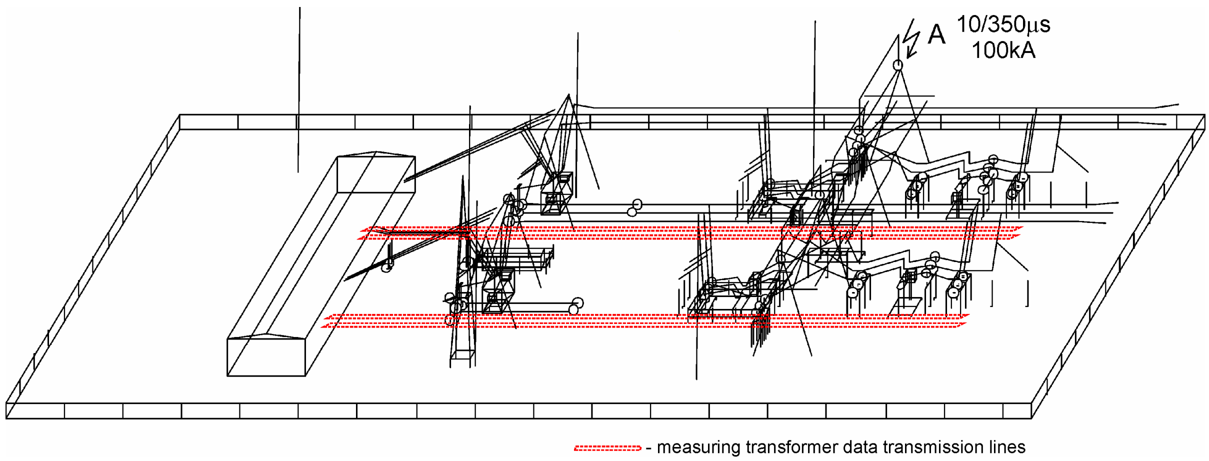

Fig.5. Configuration of HV substation S1 during the switching transient

The segments should be short enough so, that the current is assumed to vary linearly along with the segment for all analysed frequencies, but they should be also large enough to meet the thin wire approximation.
Each such segment is represented by an electric dipole located at its centre and the electromagnetic quantities at an observation point are obtained by the sum of the contributions from all of the dipoles.
The computation methodology assumes the frequency domain analysis. The field of a single dipole is expressed as the sum of the source term, the image term and the Sommerfeld integral. The Sommerfeld integrals have been computed by the Double-Integration method i.e. numerically, without any approximation [7].
In simulation of danger created by switching transients in HV system, the source of surge current was used.
The shape of this current was calculated using substitution parameters of electrical power net (Fig.6.).

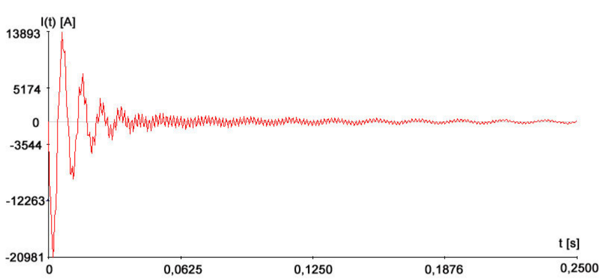

Fig. 6. The shape of excitation current that was introduced in different points of HV substation

Appointed surge current was decomposed, using program FFTSES [6], into the Fourier's series. In analysis the first 98 frequencies of surge current with the largest part of surge's energy was taken into account.
This surge current was introduced to earthed constructional element on the substation's area.

4. COMPUTATION RESULTS

The induced overvoltages at the ends of signal wires in control building have been computed using MultiFields software package, which is a part of CDEGS package. For signal wires the overvoltages, which appeared in control building between the wires, and between wires and local or true earth were calculated.
Some examples of these surge voltages in substation S1 are presented in fig. 7 and 8. Overvoltages between neighbouring wires achieve themselves small values from some to a dozen or so volts. Surge voltages about such values are not dangerous for signal ports of devices, they can only disturb signal and cause disoperation of electronic devices or systems.
In analysed arrangement of overvoltages between distant wires (Fig. 7b.) they have got considerably larger values. A few hundred volts were achieved. In these cases induced overvoltages can be dangerous only for electronic devices, which have the connections with some of the control wires.
For electronic devices more dangerous are the voltages between wires and local bounding bar in control building. These voltages can reach the values from few hundred volts up to 1 kV (Fig. 8a). Maximal values of overvoltages can reach a dozen or so kV. They appeared between the wires and remote earth (Fig. 8b).

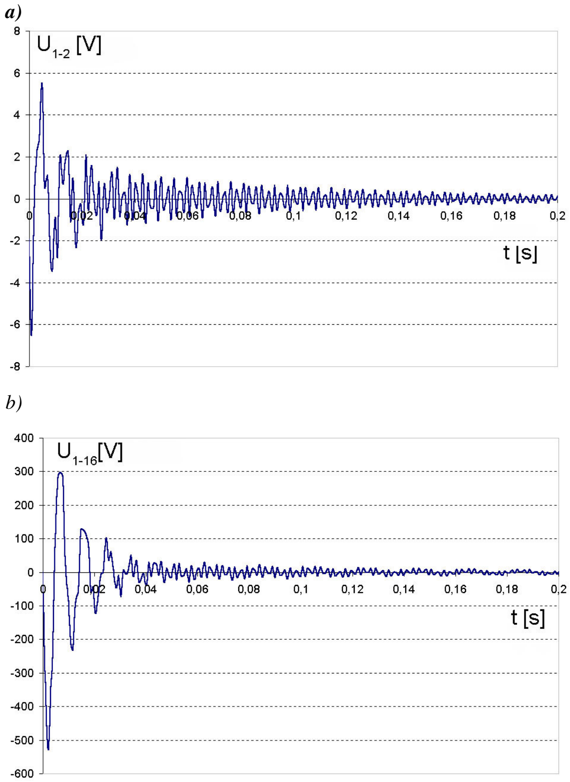

Fig. 7. Overvoltages in signal cables in HV substation between two underground wires, a) between 1 and 2, b) between 1 and 16.

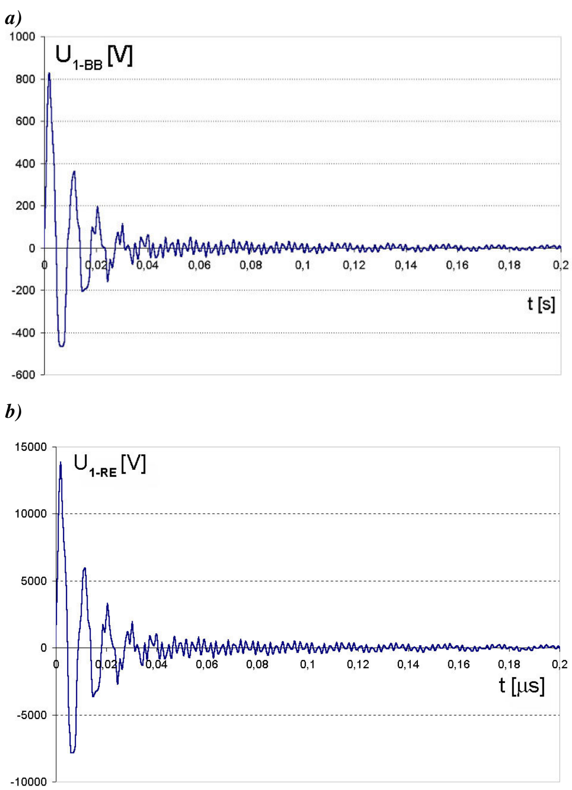

Fig. 8. Voltage in signal cables in HV substation between: a) wire and remote earth, b) wire and local bounding bar

5. CONCLUSIONS

Switching transient in high voltage HV substation can cause severe interference problems in electronic equipment and systems.

The problem with damages or misoperation caused by these overvoltages has been observed in control buildings with electronic devices in measuring and controlling systems inside HV substation.

The advantages of the proposal theoretical model of voltage surges calculation in control cables are the following:

- all possible configurations of conductive elements on the HV substation and different points of switching transient can be represented in theoretical model,
- surge voltages and currents in wires under the grounds in different configuration and in different places in substation area. Can be analysed.

The study shown that, without the surge protective devices or circuits, the values of overvoltages in control wires can reach the values, which are dangerous for electronic equipment.

Acknowledgment

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6. REFERENCES

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