Development of a Calculation Program of Induced Surge Voltages on Low-voltage Control Circuits in Power Plants and Substations
− Calculation of Induced Surge Voltages due to a Current Flowing through a Grounding Grid Using VSTL −

Background

Recently, low-voltage control circuits in power plants and substations operate with lower voltages and higher frequencies owing to the installation of digital-control equipment. This significantly increases the risk of faults of such circuits due to abnormal surge voltages in the control circuits. It is important to develop a technique for calculating lightning surge voltages in low-voltage control circuits to improve lightning-protection methodologies properly, since the percentage of faults which occurred arising from a lightning surge in low-voltage control circuits is 70 %[*1]. It is required to develop techniques for representing grounding grids, multi-core control cables, control cables with metal sheathes, switching equipment, instrument transformers and so on and an integrated calculation program based on these techniques.

Objectives

The purpose of this study is to develop a technique for applying VSTL[*2], a surge calculation program developed by CRIEPI, to the calculation of induced surge voltages on a control wire[*3] due to a current flowing through a grounding grid and validate the technique by comparing calculated results with measured ones.

Principal Results

1. A technique for representing a grounding grid and a control wire

A technique to simulate a thin wire of an arbitrary radius such as a grounding grid and a control wire in the FDTD simulation has been already proposed, and this technique is developed for a uniform grid where an analysis space is divided into numerous equally-sized cells. However, the utilization of a non-uniform grid with non-equally-sized cells is necessary to reduce the calculation burden, when VSTL is applied to the calculation of induced surge voltages on a control wire where thin wires are set in a wide area for simulating a grounding grid. We show that the technique is valid even in the non-uniform grid if the sizes of the three cells at least adjacent to the thin wire are kept uniform.

2. Surge characteristics of a grounding grid and a control wire

Firstly, as shown in Figs. 1(a) and (b), when a current was injected into a grounding grid whose size corresponds to a distributing substation area, we measured its potential rises and currents propagating through it, and compared them with results calculated using VSTL with the above technique. Figs. 1(c) and (d) show that the measured results of the potential rises and the propagating currents at the positions A and B designated in Fig. 1(a) agree well with the calculated results. Secondly, as shown in Figs. 2(a) and (b), we located a control wire over the grounding grid and measured its potential rises and voltage differences between the grounding grid and the control wire. As is shown in Figs. 2 (c) and (d), we found a good agreement between the measured and the calculated results.

Future Developments

Techniques for representing multi-core control cables and control cables with metal sheathes used in low-voltage control circuits will be developed.

Main Researcher: Akiyoshi Tatematsu, Ph. D.,
Research Scientist, Lightning & Electromagnetic Environment Sector, Electric Power Engineering Research Laboratory

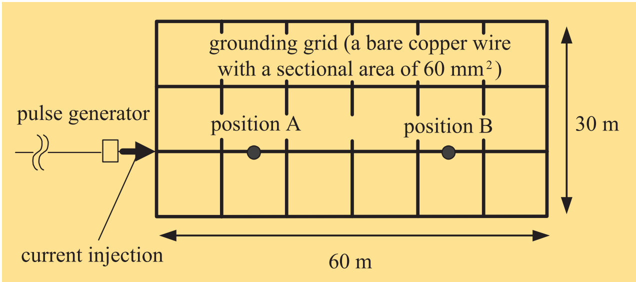
Reference

A. Tatematsu, et al., 2009, “Lighting-surge characteristics of low-voltage control circuits (No. 2) – application of VSTL to calculations of induced surge voltages on control wires –”, CRIEPI Report H08004 (in Japanese)

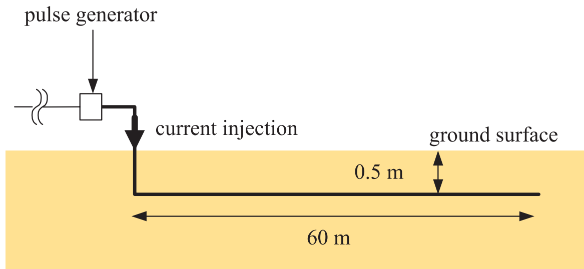
＊1：Japanese Electrotechnical Research Association, 2002, “Technologies of Countermeasures against Surges on Protection Relays and Control Systems”, ETRA Report, vol. 57, no. 3 (in Japanese)

＊2：VSTL (Virtual Surge Test Lab.) is a surge calculation program based on the numerical electromagnetic computation method.

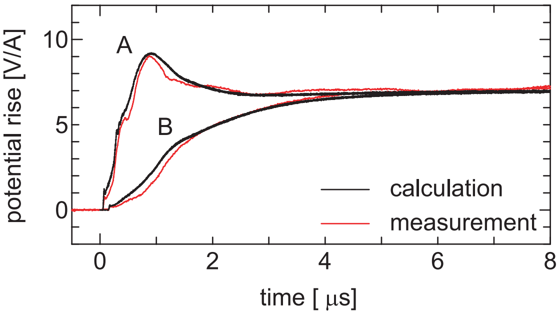
＊3：Although a control cable actually have a multi-core or a metal sheath, a control wire with a single core and without a metal sheath is used as a first step of the analysis.



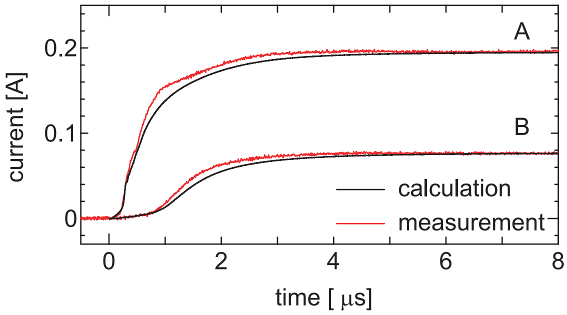
(a) Arrangement (top view)



(b) Arrangement (side view)

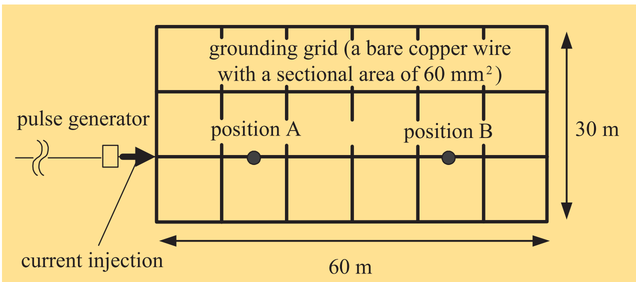


(c) Potential rise of the grounding grid

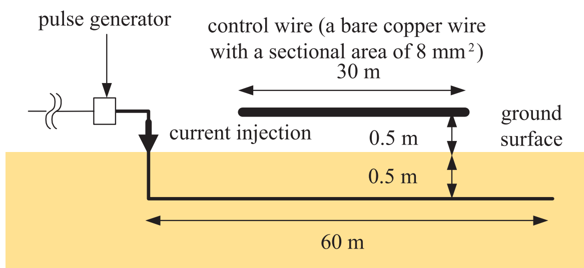


(d) Current propagating through the grounding grid

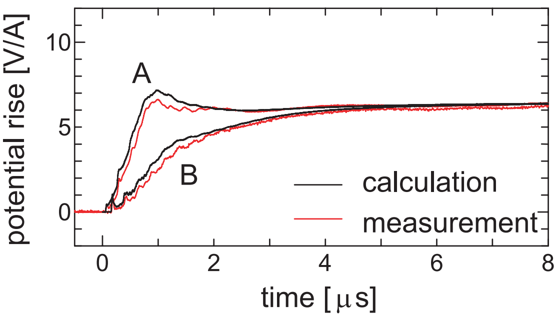
Fig.1 Surge characteristics of the grounding grid when a surge current flows into the grounding grid (without a control wire)



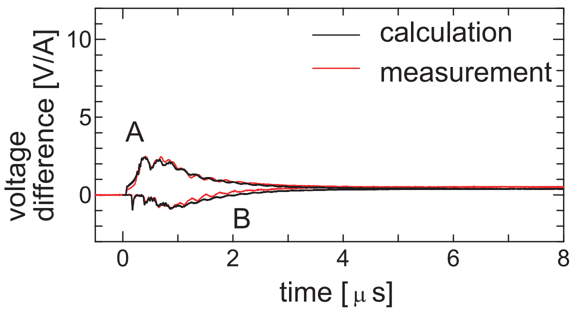
(a) Arrangement (top view)



(b) Arrangement (side view)



(c) potential rise of the control wire



(d) voltage difference between the grounding grid and the control wire

Fig.2 Induced surge characteristics of the control wire when a surge current flows into the grounding grid (with a control wire)