FDTD Simulation of Voltages Induced on Secondary Circuits in a Substation with a Grounding Grid

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Abstract—Voltages are induced on a secondary circuit in a substation owing to lightning impulse currents flowing into the grounding structure of a substation. The induced voltages may cause faults and malfunctions of sensitive electronic devices, and thus, to protect secondary circuits from lightning overvoltage, shielded control cables are employed. In this study, we simulate a test platform of primary and secondary circuits with an unshielded or shielded control cable in a substation using an electromagnetic transient analysis code developed on the basis of the hybrid technique of the three-dimensional finite-difference time-domain method and transmission-line theory. Then, we calculate voltages induced on the control cable when lightning impulse currents flow into a grounding grid, and compare the calculated results with measured waveforms for validation.

Keywords-FDTD method, lightning, secondary circuits, shielded control cable, substation

I. INTRODUCTION

When lightning strikes a substation and transmission line, lightning impulse currents flow into the grounding structure of the substation through lightning surge arresters, shield wires, and so forth. Then, voltages are induced on the secondary circuits in the substation owing to the effect of the ground potential rises of the grounding structure and electromagnetic coupling, which may cause malfunctions and faults of electronic devices in the secondary circuits. As countermeasures against lightning overvoltage, shielded control cables are installed in the secondary circuits, and thus, it is useful to evaluate the effectiveness of shielded control cables through simulations. In this study, using the hybrid technique of the finite-difference time-domain (FDTD) method [1] and transmission-line (TL) theory, we calculated voltages induced on a control cable in a test platform of primary and secondary circuits in a substation, and we compared the calculated results with measured waveforms for validation.

II. SIMULATED AND MEASURED RESULTS

Fig. 1 shows the test platform of primary and secondary circuits in a substation, which was mainly composed of a grounding grid, a gas-insulated switchgear (GIS) model comprising a gas-insulated bus model and voltage and current transformers (VT and CT), and a protection-relay unit. Here, the signal-output terminal of the CT was connected to the protection-relay unit via an unshielded or shielded control cable. In the case of the shielded control cable, the shield of the cable was grounded at both ends. Injecting a lightning impulse current into the grounding grid with a pulse generator placed near the grounding grid, we measured voltages induced on the control cable at the protection-relay unit (point A in Fig. 1). In the simulations, we modeled the grounding grid, gas-insulated bus model, shield of the control cable, and pulse generator by the three-dimensional FDTD method, whereas electromagnetic transient phenomena in the control cables were solved on the basis of the one-dimensional TL theory taking into account the effect of the surface transfer impedance of the shield of the control cable [2]. As shown in Fig. 2, we confirmed that the calculated induced voltages agree well with the measured waveforms. The hybrid technique is useful for evaluating the effectiveness of shielded control cables to suppress induced voltages.

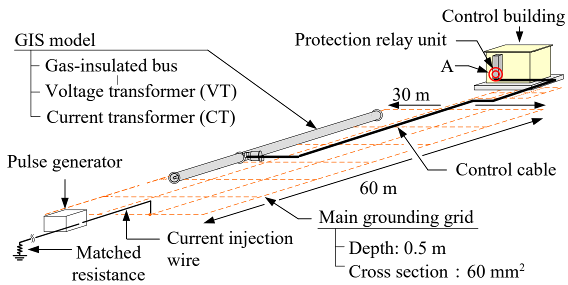
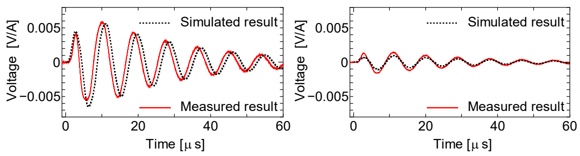


Fig. 1 Experimental setup of a test platform of primary and secondary circuits.



(a) Unshielded control cable (b) Shielded control cable
Fig. 2 Simulated and measured induced voltages at point A.

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