# Analytical Tools for Transient Phenomenon and Electromagnetic Field

## Background

Lightning is one of the main causes behind accidents involving power equipment. Once lightning strikes electric towers, power lines or buildings, the large current of the lightning propagates along the equipment themselves, transmission lines, and sometimes even the ground, and is finally discharged to the earth while generating a transient electromagnetic field. In addition, as the information society develops, the number of incidents of damage to surrounding electric machinery, such as computers, communication devices, and electric home appliances, as a result of lighting surges, is increasing.

To avoid lightning damage, it is important to simulate where the current from lightning that strikes electric towers or buildings flows and where and what kind of electromagnetic field it produces during the flow. However, it is impossible to accurately analyze the voltage caused by the lightning current (lightning surge) by conventional analytical methods, which frequently require the use of approximation. Therefore, numerical electromagnetic analysis methods to accurately treat electromagnetic phenomena are required.

Furthermore, power-electronics apparatus will be massively used for the efficient integration of renewable-energy and energy-storage apparatus into power systems. Since next-generation power-electronics apparatus will utilize very fast switching devices, conventional simulation programs cannot give accurate results for simulations of such power circuits. Thus, a new simulation method should be developed.

## Principal results

**(1)Analytical program of electromagnetic field, VSTL**

We developed a program, Virtual Surge Test Lab (VSTL) based on finite difference time domain method, which enables us to analyze the transient electromagnetic field that is produced when lightning strikes transmission towers or buildings (Fig. 1).

**(2) Analytical program of electromagnetic field, PFIT**

We developed a Parallel Finite Integral electromagnetic Transient program (PFIT) based on finite integral method. By PFIT, it is possible to analyze the transient grounding resistance of mesh electrodes, which are frequently used to be as grounding electrodes of electric equipment and buildings (Fig. 2).

**(3) Electromagnetic transient analysis program for power systems, XTAP**

We have developed a simulation program called XTAP (eXpandable Transient Analysis Program) for electromagnetic transient analysis of power systems. The program can give accurate simulation results for circuits including many switching devices (Fig. 3).

## Future Developments

We will elaborate each analytical metho andl improve the graphic user interface to increase its user friendliness.

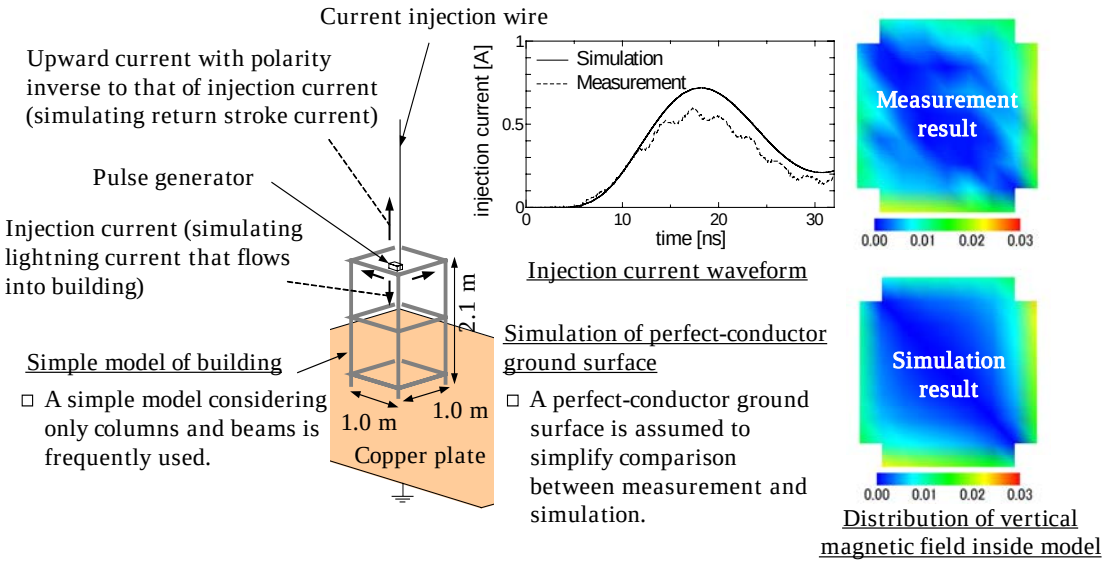
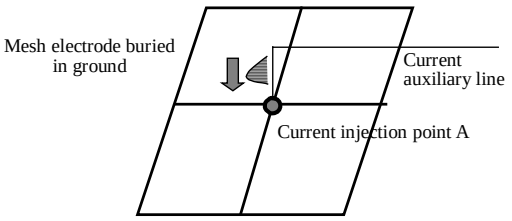
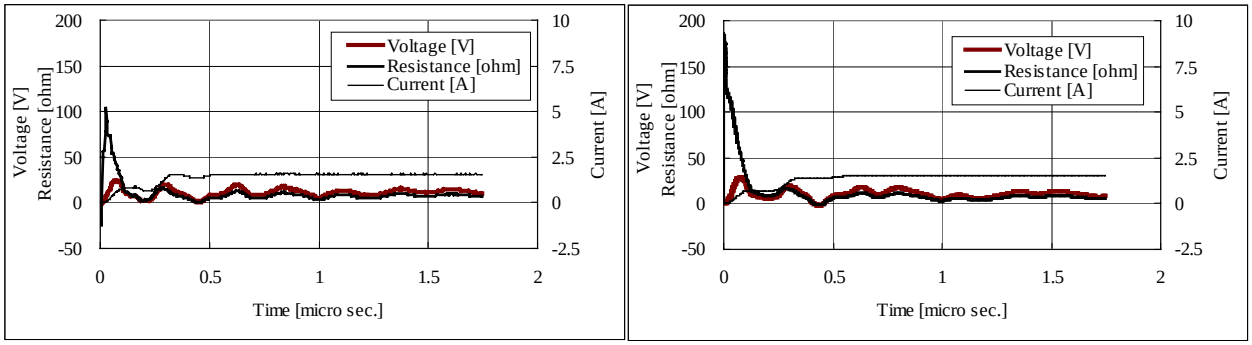



**Fig. 1 VSTL analysis of magnetic field in building**



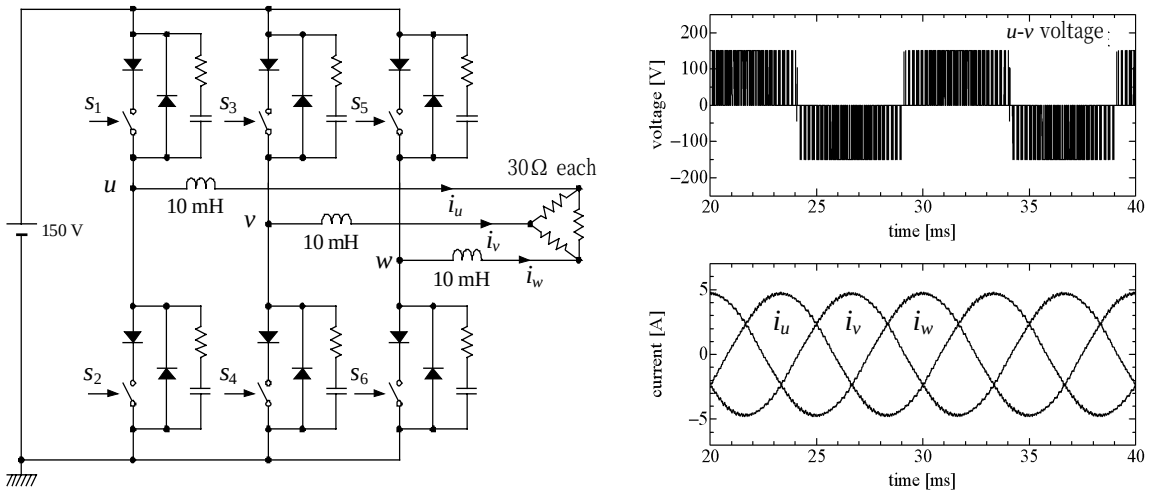

Mesh electrode composed of ϕ13 copper wires and buried at 0.5 m depth. Impulse current is injected at point A, where its potential and current are measured. The value obtained by dividing the voltage by the current at each time point is defined as grounding resistance. There is general agreement in the current, voltage, and grounding resistance between the experiment and analysis, excluding the initial current during the rise time.




1) Experimental result at point A

2) Analytical result at point A

**Fig. 2 PFIT analysis of transient grounding resistance of mesh electrode**




**(a) Circuit simulated** **(b) Simulation result by XTAP**

**Fig. 3 Simulation result of a three-phase PWM inverter circuit by XTAP.**