Project Research — **Establishment of Optimal Risk Management**

Lightning Protection for an ICT-oriented Society

Background and Objective

Recently, highly sophisticated societal systems have been constructed using information and communication technologies (ICTs). These systems, however, are vulnerable to external disturbances such as lightning. Once social infrastructures such as information networks and power supply systems stop, extraordinary confusion may occur in society.

In this project, we will further develop the lightning protection methods constructed so far and will establish novel lightning protection technologies to construct robust power supply systems in a society using information and communication technologies, taking the concept of lightning risk management into consideration.

Main results

1 Advancement of a Lightning Risk Assessment Program

New functions have been added to the lightning risk assessment program, which was developed last year for the evaluation of the lightning risk of transmission lines and the risk of instantaneous voltage dips caused by lightning. The added functions are the evaluation of the lightning risk of distribution lines and wind turbine systems (Fig. 1). In the program, relative lightning risk can be evaluated from lightning occurrence and the density of the facilities (H11008).

2 Overvoltage Characteristics Generated on Low-voltage Control Circuits and the Development of a Novel High-accuracy Analysis Scheme

To study the characteristics of surge voltages in a low-voltage control circuit, we set up a test system composed of two grounding grids, a GIS model composed of instrumental transformers (VT and CT), a digital-type protection relay equipment, and a control cable. Using this test system, we generated a very fast transient inside the GIS model, simulating the switching overvoltage, and measured the surge voltages arising in the low-voltage control. From these results, in this very-fast-transient case, we have clarified that the main cause of surge voltages is the surge transition from the primary circuit to the secondary circuit at the instrumental transformers of the VT and CT (H11015).

To predict surge voltages in the low-voltage control circuit spreading over large systems such as power plants and substations, we have developed a new surge simulation program by coupling the numerical electromagnetic analysis (the FDTD method) with the circuit analysis, which can utilize each advantage of the two analysis methods (Table 1). As a first step in applying the developed program to the surge analysis of a complicated configuration such as a low-voltage control circuit composed of a grounding grid, an instrumental transformer, protection-relay equipment, and a control cable, we calculate the induced voltages on an aerial wire over a grounding grid. The calculated results agree well with the measured results within a difference of 12%, and the validity of the developed program is confirmed (Fig. 2) (H11023).

3 Evaluation of Immunity Tests for ICT Equipment Installed at Power Stations

Immunity tests against four types of conductive noises: (1) electric fast transient/bursts (EFT/Bs), (2) rectangular impulses, (3) damped oscillatory waves, and (4) surges, are conducted for ICT equipment installed at power stations, among which equipment IP (Internet Protocol) devices were chosen. These noises are adopted in the current immunity standards. The observation showed that the interference to the IP transmission by the EFT/B noise was remarkable (Fig. 3). It was also shown that the rate of packet losses well correlated with the ratio of the duration of the noise to the period (H11022).

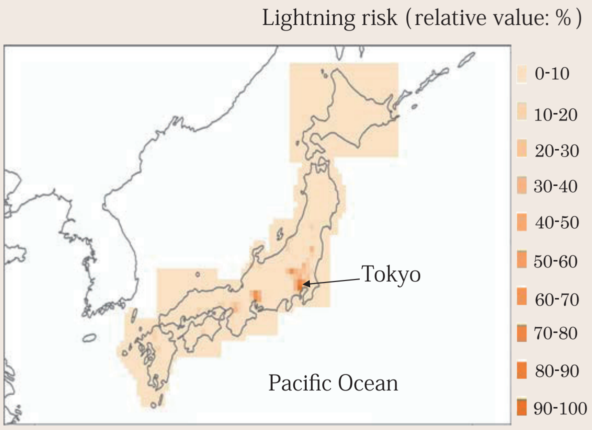
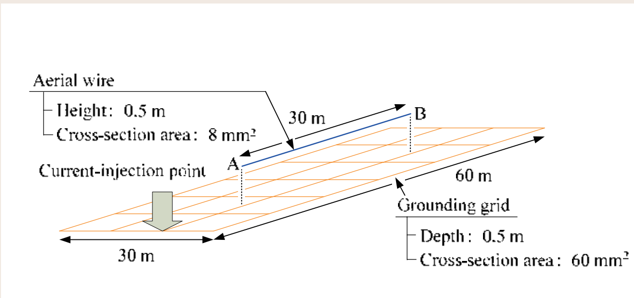


Fig. 1: An image map of the lightning risk of distribution systems

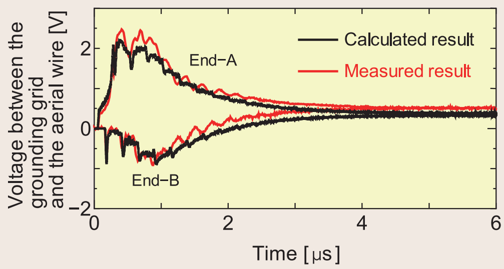
In the developed program, the lightning risk is evaluated from lightning occurrence and the density of power distribution facilities. Please note that the effects of various lightning protection is not considered in this case, and the lightning risk in a metropolitan area where the density of power distribution facilities is substantial, becomes relatively high. If the lightning protection methods are taken into consideration, the risk distribution would be different.

Table 1: Comparison between the conventional FDTD method, circuit analysis, and the FDTD method coupled with circuit analysis

Item	FDTD method	Circuit analysis	Coupled calculation
Cables such as low-voltage control cables	Considering realistic calculation time and memory capacity, modeling is impossible.	Modeling is possible, but it is impossible to consider an induction effect from other causes, such as grounding grids.	It is possible to take into account both the surge phenomena of control cables, instrumental transformers, and other equipment and the induction effect on control cables from large-scale grounding grids.
Equipment such as instrumental transformers			
Grounding structures such as grounding grids	High-accuracy calculation is possible for grounding grids only.	High-accuracy calculation is impossible.	

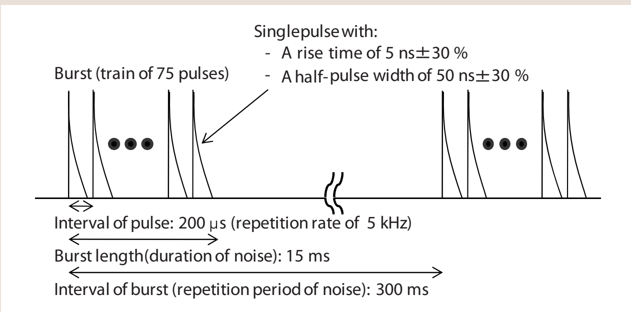


(a) Calculation arrangement

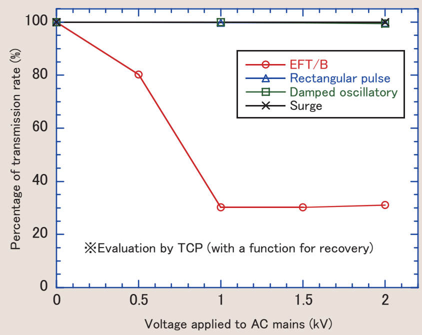


(b) Calculated results

Fig. 2: Accuracy of the surge simulation program based on the FDTD method coupled with the circuit analysis



(a) EFT/B noise test waveform



(b) Effects on the signal transmission rate

Fig. 3: EFT/B noise test waveform and examples of the evaluation of effects based on the data signal transmission rate