Development of New Method for Three-Dimensional Electromagnetic Field Analysis

Background

It is important for lightning protection that electromagnetic transient phenomena in the grounding systems of electrical apparatus and three-dimensional structures are clarified. In CRIEPI, several calculation codes based on the finite-difference time-domain (FD-TD) method have already been applied to the analysis of such phenomena. However, because of the use of a uniform grid, the codes require a large amount of computer memory for the analysis of complex structures. Therefore, it is difficult to analyze arrangements of composite materials of different electrical constants(permittivity, conductivity and permeability) such as an arrangement including stratified soils, grounding systems and three-dimensional structures.

Objectives

The objectives of this study are to develop a three-dimensional electromagnetic transient analysis code based on the finite integration technique (FIT) for calculating complex structures and stratified soils, and then to confirm the validity of the developed code by comparing the calculated result with the measured result for a three-dimensional arrangement.

Principal Results

1. Main features of the developed code

(1) Use of nonuniform grid

The analysis code using a nonuniform grid, which enables the application of a fine grid to a complex structure region and a coarse grid to another region, was developed. The analysis code does not require a large amount of memory in comparison with an ordinary code using a uniform grid and enables the calculation of more complex structures.

(2) Formulation using electric field and magnetic flux density

An ordinary FDTD method uses electric and magnetic fields as variables. Therefore, its calculated magnetic field does not satisfy the continuity of the normal component of the magnetic flux density at the interface between two media of different permeabilities such as air and iron, and soil and iron. This results in the calculation error of the magnetic field at the interface. The FIT uses electric field and magnetic flux density as variables, and satisfies the continuity. Therefore, it does not yield the calculation error at the interface.

2. Confirmation of validity of analysis code

The analysis code was applied to analyze a transient state grounding resistance (hereafter referred to as TGR) at the rectangular parallelepiped electrode arrangement shown in Fig.1. The calculated results agreed with the measured results very well. Thus, the validity of the analysis code was confirmed.

3. Application of the analysis code to the transient state analysis of the grounding resistance of a tower foot model in stratified soils

The analysis code was applied to the TGR analysis of a tower foot model in stratified soils, and then the effect of the conductivities of the stratified soils on the TGR was clarified. Fig.2 shows the calculated results in the case of a tower foot model in contact with two soils. In the case where the conductivity of the lower soil was 10 mS/m, the grounding resistance obtained using the analysis code was 2.8 Ω at 6 μs, while the steady state grounding resistance obtained by electrostatic field calculation was 2.5 Ω. These resistance values agreed with each other very well. Thus, the analysis code was confirmed to be capable of analyzing the TGR of the tower foot model in stratified soils.

Future Developments

In order to apply this code to a more complex grounding system, its vectorization and parallelization will be performed and a new analysis method capable of analyzing a more general structure including that of diagonal bracing will be developed.

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References

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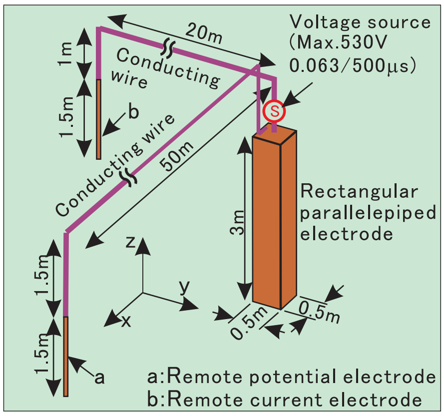
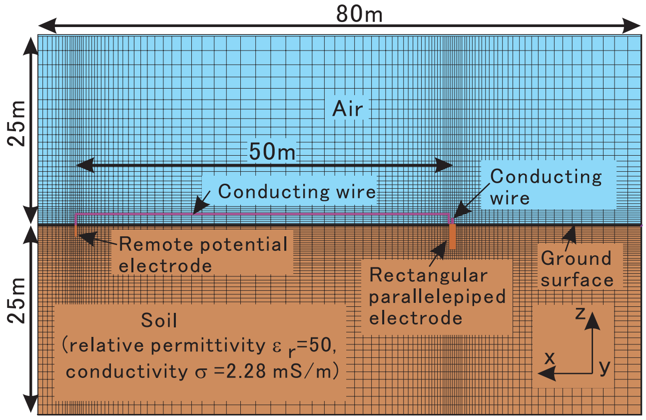
[2]K.Tanabe, 2000, “Verifying the novel method for analyzing transient grounding resistance basded on the FD-TD method throughcomparison with experimental resilts”, CREPI Report T99043(in Japanese).

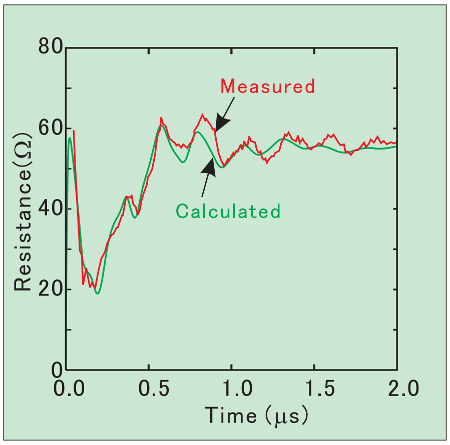


(a) Experimental arrangement[2]

(Electrodes are buried in the ground (Fig.1(b))

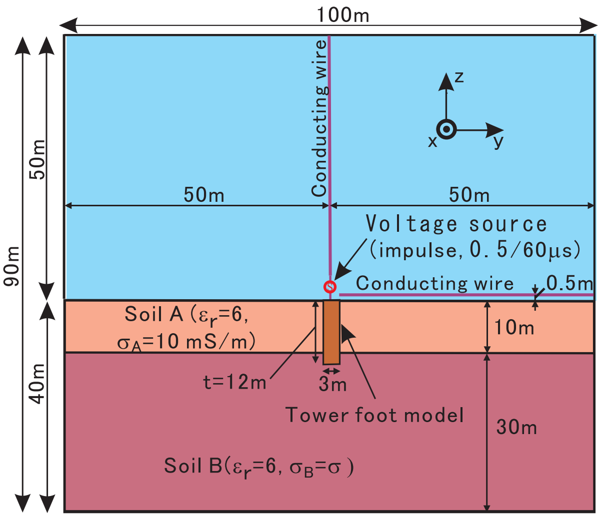


(b) Nonuniform grid

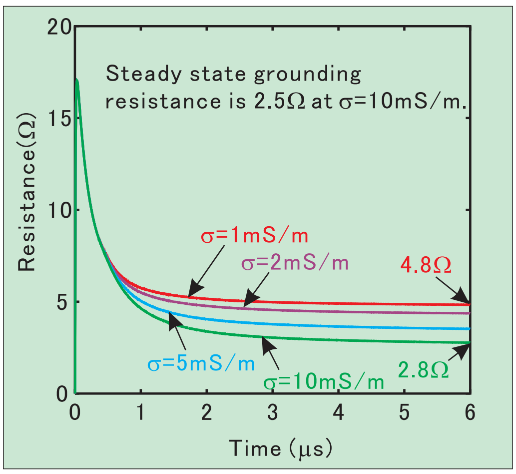


(c) TGR

Fig.1 TGR analysis of the rectangular parallelepiped electrode arrangement.



(a) Simulation model



(b) TGR

Fig.2 TGR analysis of the tower foot model in stratified soils.