Research on Grounding Grids Imaging Reconstruction Based on Magnetic Detection Electrical Impedance

Liu Kai[1], Yang Fan[1], Zhang Songyang[2], Zhu Liwei[3], Hu Jiayuan[3], Wang Xiaoyu[3], and Shen Xiaoming[3]

[1] *State Key Laboratory of Power Transmission Equipment & System Security and New Technology, Chongqing University, Chongqing,* CO 400044 *China*
[2]*State Grid Henan Electric Power Corporation Research Institute, Zhengzhou,* CO 450052 *China*
[3] *State Grid Zhejiang Electric Power Company Metering Center, Hangzhou,* CO 310014 *China*

The corrosion and breakpoints of grounding grid will directly affect its ground performance. This paper proposes a resistivity reconstruction method based on magnetic detection electrical impedance tomography (MDEIT) to measure the topology and breakpoints of grounding grid. Firstly, this paper describes the forward problem of grounding grid in MDEIT, and calculates the magnetic field distribution above grounding grid. Then, the resistivity reconstruction method based on regularization method is proposed. Finally, this paper verifies the feasibility of the proposed method by a numerical example, which show that the proposed method can be applied to measure the topology and breakpoints of grounding grid.

***Index Terms*—Image reconstruction, Fault protections, Magneto electrical resistivity imaging technique, Electromagnetic fields**

I. INTRODUCTION

GROUNDING grids are important for the safety of operators. With increase of running time, grounding faults due to corrosion or break rarely happen[1]. The electricity companies are constantly searching for techniques to measure the topology and breakpoints of grounding grid.

The magnetic detection electrical impedance tomography (MDEIT) is an imaging technique to reconstruct resistivity distributions of the imaging object. MDEIT is technically based on generating a current distribution inside of the object and measuring the magnetic field distribution outside of the object to reconstruct resistivity distributions of the imaging object. The concept of MDEIT was introduced in [2] and MDEIT was used to reconstruct cross-sectional conductivity distributions of the human body in [3]. Ref. [4] demonstrated the technical feasibility of MDEIT data acquiring.

This paper describes the forward and inverse problem in grounding grid imaging based on MDEIT. A numerical example verified the feasibility that the proposed method can be used to measure the topology and breakpoints of grounding grid.

II. THE FORWARD PROBLEM OF GROUNDING GRID IN MDEIT

A. *The calculating model of forward problem*

The analysis in this paper is based on the following basic assumptions.

(1) The current field meets the quasi-static condition;

(2) There are not any current source inside the imaging object;

(3) The resistivity of the imaging object is isotropic;

Based on the above assumptions and Maxwell equations, the forward problem in MDEIT can be simplified as

$$\nabla \times H = \boldsymbol{J} \tag{1}$$

$$\nabla \times E = 0 \tag{2}$$

Equation (1) meets

$$\nabla \cdot \nabla \times H = \nabla \cdot \boldsymbol{J} = 0 \tag{3}$$

Assuming

$$E = -\nabla \varphi \tag{4}$$

So that (3) can be descripted as:

$$\nabla \cdot \sigma \nabla \varphi = 0 \tag{5}$$

Where σ is the conductivity.The boundary conditions on the current injecting and outflowing surface is as following.

$$-\sigma \frac{\partial \varphi}{\partial n} = \boldsymbol{J}_n \tag{6}$$

Where $\boldsymbol{n}$ is normal vector, $\boldsymbol{J}_n$ is the injecting current density of boundary surface *S*, Assuming that the current density of boundary surface is homogeneous, $\boldsymbol{J}_n$ can be descripted as

$$\mathrm{J}_{n+} = \frac{I}{A_+}$$

$$\mathrm{J}_{n-} = \frac{I}{A_-}$$

Where A_+ is the area of current injecting surface and A_- is the area of current outflowing surface. So that,

$$-\sigma \frac{\partial \varphi}{\partial n} = \begin{cases} -J_{n+} = I/A_+ \text{ ,} & \text{the current injecting surface} \\ -J_{n-} = I/A_- & \text{, the current outflowing surface} \\ o & \text{other} \end{cases}$$

According to (5) (6), we can use finite element method to calculate φ, and the current density can be calculated by following equation

$$\mathrm{J} = -\sigma \nabla \varphi \tag{7}$$

Based on Biot-Savart law, the magnetic flux intensity *B* is

$$B(\mathrm{r}) = \frac{\mu_0}{4\pi} \int J(\mathrm{r}) \times \frac{\boldsymbol{r} - \boldsymbol{r}'}{\left|\boldsymbol{r} - \boldsymbol{r}'\right|^3} dV \tag{8}$$

B. *The numerical example*

The numerical example features a 2 m×2 m square grid with 1 m×1 m meshes. The current 10 A is injected in the grid, and the measurement surface is at h = 0.8 m as shown in Fig.1. According to (8), the magnetic flux density on the measurement surface shown in Fig.2.

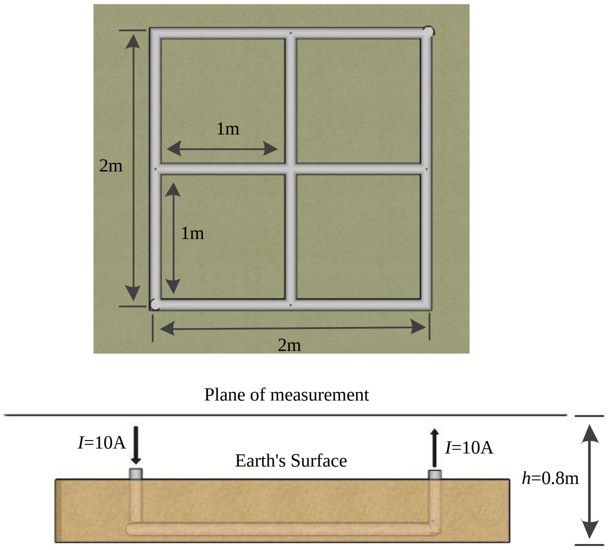

Fig.1 The simplified grounding grid model

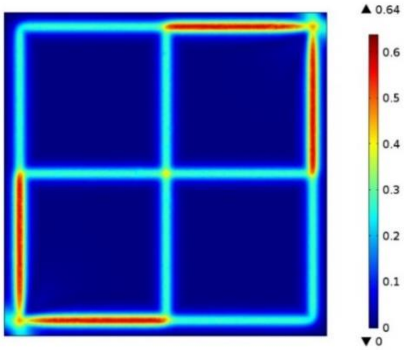

Fig.2 The magnetic flux density on the measurement surface

III. THE INVERSE PROBLEM IN GROUNDING GRID IMAGING

A. *The calculating model of inverse problem*

According to (7) and (8), the relationship between the measured external magnetic flux density **B** and the conductivity distribution σ can be written as following,

$$B = F(\sigma) = \frac{\mu_0}{4\pi}\int -\sigma\nabla\varphi \times \frac{\boldsymbol{r}-\boldsymbol{r}'}{\left|\boldsymbol{r}-\boldsymbol{r}'\right|^3}dV \tag{9}$$

Equation (9) can be written in matrix form

$$\Delta B = S\Delta\sigma \tag{10}$$

Where S is the sensitivity matrix. This paper measure the external magnetic flux density B above ground surface to reconstruct the conductivity distribution.

In the reconstruction procedure, iterative method is used for calculating the conductivity σ, and the iterative equation is following,

$$\sigma_{n+1}=\sigma_n+\Delta\sigma \tag{11}$$

Δσ can be calculated by using truncated singular value decomposition (TSVD). The resistivity distribution δ can be calculated according to (12).

$$\delta=1/\sigma \tag{12}$$

B. *The numerical example*

The numerical example features a 2 m×2 m square grid with 1 m×1 m meshes, and its resistivity distribution is shown in Fig.3. The red region and the blued region represent soil region and steel of grounding grid respectively.

The current 10 A is injected in the grid, and the external magnetic flux density B above ground surface is measured. According to the reconstruction algorithm proposed, the resistivity distribution can be reconstructed as shown in Fig.4.

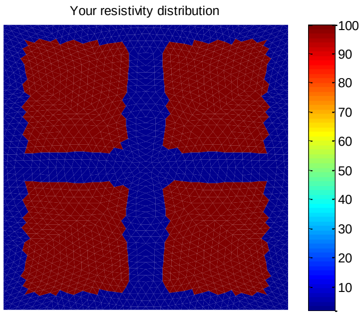

Fig.3 The resistivity distribution of grounding grid model

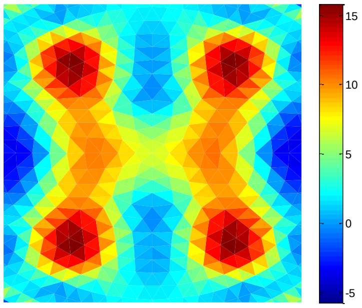

Fig.4 The reconstruction result of resistivity distribution

Fig.4 shows that the resistivity of red region is high, this region represents the soil region and its position is same with the soil region of Fig.3. It can be seen from Fig.4 that the resistivity reconstruction method can be used to measure the topology and breakpoints of grounding grid

IV. CONCLUSION

This paper propose a resistivity reconstruction method of grounding grid based on MDEIT. Then, the forward and inverse problem are derived, and the feasibility of the proposed method is verified by a numerical example which show the resistivity reconstruction method can be used to measure the topology and breakpoints of grounding grid.

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