

Yang LIU, Xiang CUI, Zhibin ZHAO

# A magnetic detecting and evaluation method of substation's grounding grids with break and corrosion

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**Abstract** The grounding grid buried in the earth will become a hidden danger to the safety of substations due to some faults of breaks or thinner conductors in corrosion. A novel method to get accurate status of grounding grid was proposed based on measuring magnetic induction intensity. The basic structure of grounding grid without working drawing was concluded, and the positions and the status of faults were diagnosed by this method. The completed detecting system, including hardware device of data measurement, diagnosis, and analysis software, was introduced concisely. The results of simulations and applications show that this method is simple and effective in the practical engineering.

**Keywords** grounding grid, fault status, magnetic induction intensity, diagnosis

## 1 Introduction

The grounding grid is an important measure to keep stable operation of system and safety of operators or power apparatus. The safety functions of grounding grid are often seriously affected by some facts including unqualified jointing while building, corrosion, and electromotive force of grounding current. These faults often lead to large economical loss.

Grounding grids are buried in soil; therefore, it is difficult to acquire their information. It is a very important problem remained to be resolved to diagnose the faults condition of grounding grids without substation operation stopped and grounding grid dug out. In recent years, this

problem has been paid attention to by many scholars [1,2]. Some of them use the electric model and meshwork theory [3–5]. These methods depend on the measurement of resistances between two ground lead wires. The others solved the problem by measuring the surface potential difference [6]. In fact, all these methods have difficulty in diagnosing the faults. It is inaccurate to get the corrosion status of conductors and the positions of broken points. Even if the grounding grid has been eroded a lot in one place, some electromagnetic parameters are still as normal as usual. Someone explored a method by computing and analyzing the surface electric and magnetic fields in 1986 [7]. However, this work is out of in-depth study and actual application. In reality, diagnosis methods are mostly based on theory analysis, and a diagnosis system that can be used to practical engineering is absent. A new diagnosis method based on measuring the surface distributions of magnetic induction intensities is presented in this paper. The basic diagnosis procedure is as follows: an exciting current of sine wave is injected directly into grounding grids by two lead wires, and then, the distributions of the surface magnetic induction intensities are measured. At last, the corrosion status or broken points of the mesh conductors and positions of faults will be concluded by analyzing the distribution characteristics and comparing with the results of the normal simulation calculations. Moreover, sometimes we can meet conditions that the working drawing of grounding grid is lost in old substations. An idea to conclude the position and structure of the grounding grid is also given by this method in this paper.

## 2 Simulation calculations

To demonstrate the feasibility of the new method and conform to the technical way of diagnosis, simulation calculations will be carried out by using our grounding analysis software package whose efficiency has been tested in lots of papers [8–11].

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Yang LIU (✉), Xiang CUI, Zhibin ZHAO  
School of Electrical and Electronic Engineering, North China Electric Power University, Baoding 071003, China  
E-mail: hdwly@163.com

The grounding grid of a 220 kV substation is used for simulation calculations, it is buried in about 0.8 m depth in earth, and its structure is shown in Fig. 1. There are nine conductors in  $x$  direction and ten in  $y$  direction. The sectional area of each conductor is  $40\text{ mm}\times 6\text{ mm}$ , the resistivity of the mesh conductor is  $1.78\times 10^{-7}\ \Omega\cdot\text{m}$ , and relative conductance is 636. The soil is defined to be only one layer, and its resistivity is  $120\ \Omega\cdot\text{m}$ .

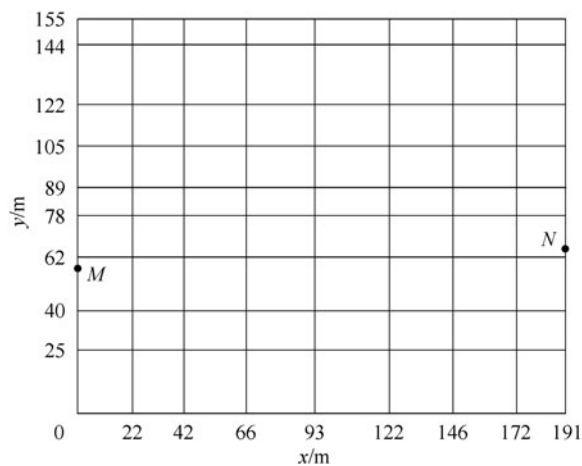


Fig. 1 Grounding grid of a 220 kV substation

Now, a sine wave signal of current intensity being 10 A and the frequency being 300 Hz is injected directly into the grounding grids from the point  $M$  (0 m, 59 m) and returned from the point  $N$  (191 m, 64 m) in Fig. 1. We define  $B_x$  as the component of the surface magnetic induction intensity in  $x$  direction and  $B_y$  as the component in  $y$  direction. The results of simulation calculations are shown in Fig. 2. We can see in Fig. 2 that the distributions of  $B_y$  present some regulars; there is a peak value corresponding each conductor in the  $y$  direction; on the other hand, the values of  $B_y$  change gently, and there is no sudden change or drop-off in  $x$  direction. Once the grounding grid has been eroded a lot or broken in one place, these distribution characteristics must be changed, and this will provide evidence for the diagnosis.

### 3 Diagnosis systems

The whole diagnosis system consists of two parts, as shown in Fig. 3: data measuring device and the diagnosis and analysis software. The data measuring device is an intelligent measuring wheelbarrow. It is made of measuring wheel, exploration coil, notch filter, amplifier, band-pass filter, data gathering card, and computer. One wheel of the wheelbarrow is used to measure the position signal. At the same time, exploration coil is used to translate signal of magnetic induction intensity into voltage signal, and then,

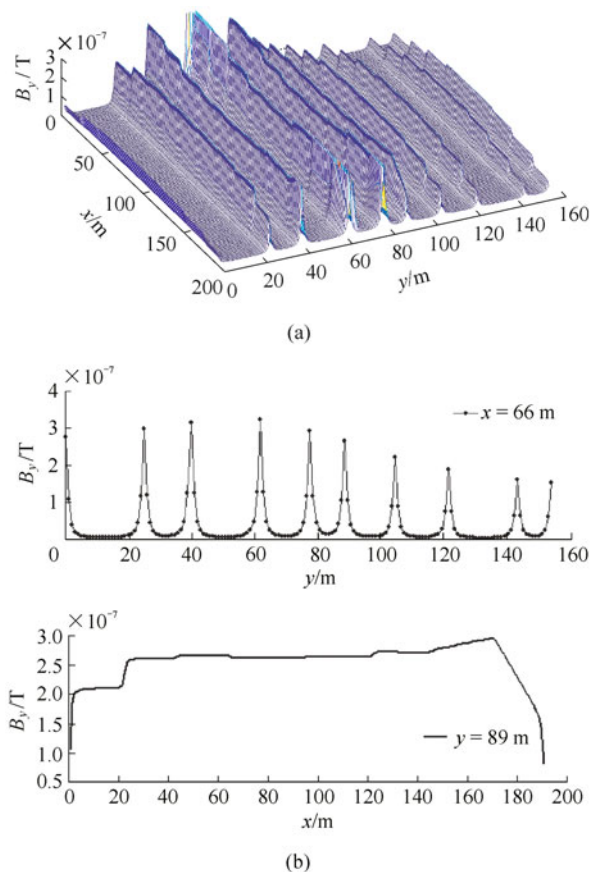


Fig. 2 Calculation results of  $B_y$ . (a) Distributions of  $B_y$  in the whole area; (b) distributions of  $B_y$  in local area

the signal is managed by filtering and amplifying. The signals of position and voltage are all input into the computer by the data gathering card. All data are memorized and managed based on the analysis software in the computer. Last, the diagnosis results are reported on the screen of the computer.

### 4 Structure judgment of grounding grid

Sometimes, we can meet the conditions that the work drawing of the grounding grid is lost, or there are bigger errors between the work drawing and the reality grounding grid during detecting process. The structure of grounding grid must be concluded first in view of these conditions. According to above simulation results in which each peak value of the surface magnetic induction intensity will correspond to a conductor of grounding grid, the structure of the grounding grid can be concluded based on measuring the distributions of the surface magnetic induction intensities. The practical judgment method is given by the following test. The judging test of structure of grounding grid is educated in a 220 kV substation. The judgment contains the following steps:



Fig. 3 Measuring systems

1) A current of frequency being 300 Hz is injected into the grounding grid by the touchable down-lead conductors connected to the grounding grid. The length of the surface back-flow line is 200 m. The current intensity and the gain parameter of the measuring system are adjusted. At the same time, the output signal wave shape is investigated.

2) Measurement starts when the signal can be distinguished and with no distortion. We regard the injecting point of the current as the original point, and setting up a coordinate as shown in Fig. 4.

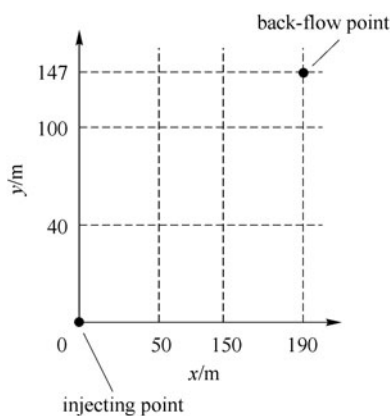
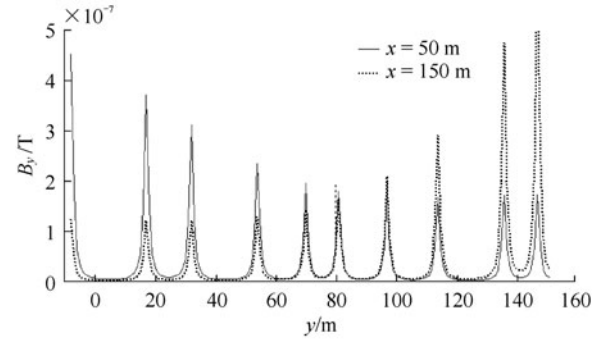
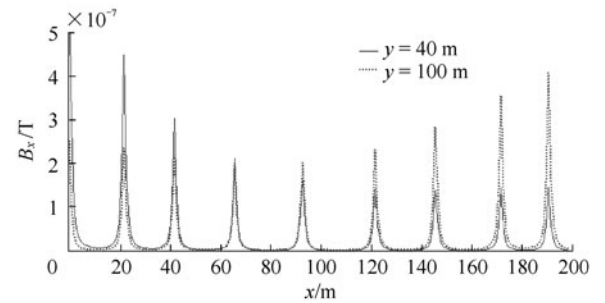


Fig. 4 Coordinate series built by injecting point

3) We separately select two measuring position lines in the  $x$  direction and  $y$  direction, for example,  $x = 50$  m,  $x = 150$  m and  $y = 40$  m,  $y = 100$  m. The components of magnetic induction intensity are measured by the measuring wheelbarrow, and the position coordinates is recorded. The measuring results are shown in Fig. 5.



(a)



(b)

Fig. 5 Measuring results of magnetic induction intensities. (a) Distributions of  $B_y$  of judging conductors in  $y$  direction; (b) distributions of  $B_x$  of judging conductors in  $x$  direction

4) We can see in Fig. 5(a) that there are ten couples' peak values of components of magnetic induction intensities in the  $y$  direction. Therefore, we conclude that there are ten correspondence conductors along the following lines:  $y = -10$  m,  $y = 17$  m,  $y = 33$  m, ...,  $y = 147$  m. We also conclude similarly that there are nine conductors along the lines:  $x = 22$  m,  $x = 42$  m, ...,  $x = 190$  m from Fig. 5(b). We draw these lines of conductor positions along the  $x$  direction and  $y$  direction in the coordinate shown in Fig. 4. Then, we can obtain the basic structure figure of the grounding grid shown in Fig. 1, and then, we contrast the judgment drawing with the practical work-drawing of the grounding grid. The result is satisfying and shows that the above judgment method is correct.

## 5 Application of fault diagnosis

In the interest of verifying the feasibility of the method and the reliability of the system, practical examinations and measurements have been carried out in a 110 kV substation built in 1984. Figure 6 shows the main structure of the grounding grid. The mesh conductors are made of galvanization flat steels whose section area is  $40 \text{ mm} \times 6 \text{ mm}$ , and the burying depth is 0.8 m. Its resistivity is  $1.78 \times 10^{-7} \Omega \cdot \text{m}$ , and relative conductance is 636.

The feasibility of the diagnosis method has been tested

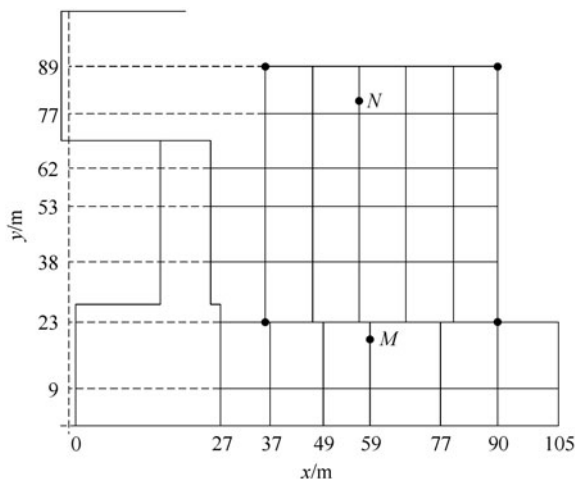


Fig. 6 Grounding grid of a 110 kV substation

by measuring the surface magnetic induction intensities. First, an exciting current signal whose current intensity is 8 A and frequency is 300 Hz is injected into the grounding grids from the point  $M$  (59 m, 21 m) and returned from the point  $N$  (57 m, 80 m), as shown in Fig. 6. During the detecting process, the distributions of the surface magnetic induction intensities in  $x$  direction and corresponding position coordinates are recorded by the detecting system. The results are shown in Fig. 7. We can find in Fig. 7 that the distributions of the surface magnetic induction intensities are very irregular, and the values of  $B_x$  in some local area have fallen obviously. The results are very different from those obtained from simulation calculations. Therefore, we can suppose that the grounding grids may be eroded seriously. The substation was enlarged and examined in 2006. We find that a lot of section conductors have been eroded indeed, and broken points appear when the grounding grid has been dug out. Hidden trouble to safety has been banished after the whole grounding grids have been repaired and laid newly. The detecting example shows that the new method is practical, and the capability of the detecting system is satisfying.

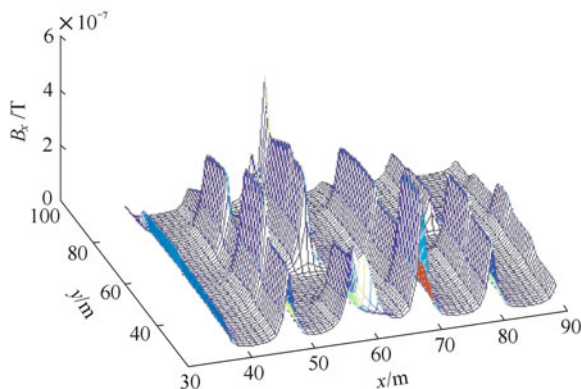


Fig. 7 Distributions of surface magnetic induction intensities

## 6 Conclusion

Detail principle of the new method to diagnose the corrosion situation and broken point sites of the grounding grid is described in this paper. The realization of a diagnosis system is introduced simply. All results of the simulation calculations, experiment of judgment structure, and applications of diagnosis fault show that the new diagnosis method is feasible. The detecting system is efficient and can be used in engineering practice.

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