Application of High Density Electrical Method Based on Numerical Simulation in Hydrogeology and Engineering Geology

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Abstract: as a New Type of Electrical Prospecting Method, High Density Electrical Prospecting Method Can Effectively Reduce Electromagnetic Interference and Faults and Improve the Working Efficiency and Accuracy of Exploration. Therefore, High Density Electrical Prospecting Method Has Been Widely Applied in Hydrogeology and Engineering Geology. Based on the Numerical Simulation Around the High-Density Electrical Method, This Paper Explains the Basic Principle of the High-Density Electrical Method, Introduces the Advantages and Working Methods of the High-Density Electrical Method and Its Application in Practice. High Density Electrical Method is Playing an Increasingly Important Role in the Exploration of Hydrogeology and Engineering Geology.

1. Introduction

The Density of Measuring Points of High Density Resistivity Method is Relatively High, and the Amount of Information Obtained is Relatively Large, Which is the Concentration of Electrical Profiling Method and Electrical Sounding [1]. It Has a Wide Range of Applications, Especially in Hydrogeology and Engineering Geological Exploration. When This Exploration Method is Used for Field Measurement, All the Electrodes Are First Concentrated on One Section, Then the Data Are Converted by Using the Electrode Conversion Switch, and the Data Are Collected by Using the Electric Measuring Instrument [2]. for Example, Pipeline Detection, Groundwater Search, Mining Area Detection and Different Types of Strata Division, Etc. Different Geotechnical Structures Have Different Conductivity. in the Process of Detection, When a Stable Current Field is Established Underground, Its Distribution Law Depends on the Occurrence of Different Electrical Layers [3]. This Electrical Prospecting Method Can Effectively Reduce Electromagnetic Interference and Failure Rate during Operation, and Can Improve the Accuracy and Speed of Geological Exploration. with the Continuous Development of Survey Science and Technology and the Needs of National Economic Construction, as a New Geophysical Method, High-Density Electrical Method Will Be Widely Used in Engineering Geology, Hydrogeology and Other Related Fields.

2. Summary of High Density Electrical Method

2.1 Principle of High Density Electrical Method

The Operation Principle of High Density Resistivity Method is Similar to That of Ordinary Resistivity Method. the Main Difference is That High Density Resistivity Method is an Array Exploration Method, and the Density of Observation Points is Relatively High in Actual Operation. High Density Resistivity Method is Essentially Direct Current Resistivity Method. However, the Actual Supply Current is Low-Frequency Alternating Current. the Power Supply Frequency is Fixed and Generally Selected between 20 and 30 Hz [4]. the High Density Electrical Method Has High Density of Measuring Points, the Distance between Points is as Small as 1 ~ 2 m, and It Has Double Properties of Depth Measurement and Profile Measurement. High Density Electrical Method Has Small Point Distance, High Data Density and High Efficiency. It is a Dc Resistivity Method, and the Measurement Result of Two-Dimensional Resistivity Section [5]. High Density

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Electrical Method Can Reflect the Abnormal Form of Underground Electric Body More Intuitively and Accurately. Because the High-Density Electrical Method Can Adopt a Very Flexible Electrode Arrangement and Combination Mode, Different Kinds of Measurement Schemes Can Be Realized under Different Electrode Arrangement Modes, and Multi-Directional Geoelectric Section Data Can Be Obtained [6]. This Method is Array Exploration. the Specific Working Principle of High-Density Electrical Method is to Place All Electrodes on the Profile during Field Work, and Then Use the Program-Controlled Electrode Change-over Switch and Electrical Measuring Instrument to Realize Data Acquisition.

2.2 Advantages of High Density Electrical Method

High density electrical method can complete the electrode arrangement work at one time, which can effectively reduce the fault and electromagnetic interference, and greatly improve the efficiency. The electrical characteristics, shape, scale and extension trend of geological target layer can be directly displayed by digital transfer and image section. In fact, the high-density electrical method is an array exploration method, which studies the distribution of underground stable current field in two-dimensional space [7]. Data acquisition realizes continuous rolling scanning measurement through computer control, avoiding the artificial interference of electrode movement. In addition, with the development of geophysical inversion methods, resistivity imaging technology of high density resistivity data has also developed from one-dimensional and two-dimensional to three-dimensional, greatly improving the interpretation accuracy of geoelectric data [8]. Abundant geoelectric section information can be obtained to realize automatic or semi-automatic field data acquisition. After years of development, high density electrical method has become increasingly mature and perfect, with outstanding technical performance and advantages. In the field of hydrology and engineering geology, high density resistivity method has been paid more and more attention.

2.3 Principle of High Density Electrical Method

On-site measurement refers to the arrangement of measuring lines and measuring points. After pre-selection, all electrodes are arranged at certain intervals of measuring points, and then through the special electrodes required by the conversion device, these electrodes are combined into the specified electrode device and electrode spacing [9]. Through these data, we can finally obtain that the observed resistivity section has an inverted trapezoidal shape. These data can be processed to draw a resistivity profile. The observation of various electrode devices and the observation of multiple electrode distances are rapidly completed at multiple measuring points of the observation profile resistivity method. If all instruments and equipment of high density electrical method are controlled by computer, the data collection, processing, analysis and mapping can be automated. For the cross section with large terrain change, the altitude coordinates are added to the data file for terrain correction during inversion. After the repeated calculation of the data collected in this field, the collected data is converted into the relation of resistivity [10]. After a series of data processing, these apparent resistivity values can be drawn into a section map of apparent resistivity distribution. The map can reflect the distribution of underground strata, geological structure and other geological conditions.

3. Realization of Value Simulation in Ansys

In the actual operation process of mathematical and physical equations, the boundary value problem is composed of partial differential equations and corresponding boundary conditions. Since the boundary value problem is equivalent to the variational problem, the solution to the variational problem is the solution to the global value problem. In practical engineering applications, people pay more attention to the time-average value of flow, while ignoring the details of turbulence. The internal configuration division of meandering river sand body is guided by modern sedimentation and field outcrops of meandering river point bar sand body. Based on the identification of point bar sand body, model prediction is carried out by using dense well pattern data to achieve the purpose

of reasonable combination of crosswell lateral lamination distribution. Confirm or falsify the existing geological model from the mathematical theory and method, and establish the geological structure model that conforms to the actual situation of regional geology. Therefore, based on the comprehensive analysis of the existing data, a reasonable geological model is constructed, and the initial conditions, boundary conditions and experimental parameters of the experimental study are selected from different aspects. A homogeneous and anisotropic equivalent element of rock mass is used to simulate the structural effect of faults. If there are multiple layers passing through the rock mass unit, the unit can be regarded as a composite unit composed of multiple layers and faults. At the same time, this equation can allow the existence of velocity gradient in underground medium, and the velocity of medium can change in space. According to the characteristics of non-reflection wave equation, the self-excited self-recovery time profile is synthesized by using the explosion panel method. The object studied by the method is the stable current field in the underground half space. In order to reduce the calculation workload, the calculation range is usually limited to a limited solution area when solving boundary value problems.

In the linear source field, the electric field and conductivity of rock and soil do not change along its direction (Y direction). Therefore, the analytic function of potential is a function of (x, z), namely σ: σ (x, z) and u=u(x, z), and the two-dimensional partial differential equation of potential U(x, z) is:

$$\frac{\delta}{\delta x}\left(\sigma\frac{\delta U}{\delta x}\right)+\frac{\delta}{\delta x}\left(\sigma\frac{\delta U}{\delta z}\right)=f \tag{1}$$

The object studied by electrical method is the stable current field in the underground half space. In order to reduce the calculation workload, the calculation range is usually limited to a limited solution area when solving boundary value problems. Due to the continuity of potential, at the interface:

$$U_1(x_1 z)=U_2(x_1 z) \tag{2}$$

Due to the continuity of the normal component of current density, there are:

$$\sigma_1\frac{\delta U_1}{\delta n}=\sigma_2\frac{\delta U_2}{\delta n} \tag{3}$$

Where n is the outer normal direction of the interface.

As can be seen from Table 1, the simulated errors are all small and meet the precision requirements of numerical calculation. With the increase of the polar distance, the simulation accuracy is higher. This is because the larger the polar distance, the more reasonable the grid between the power supply electrode and the receiving electrode, and the closer the result is to the theoretical solution.

Table 1 Comparison between Finite Element Calculation Results and Analytical Solutions of Potential Difference in Geoelectric Section of Point Power Layer

X(m)	Analog calculation of potential difference	Theoretical calculation of potential difference
1.3	20.36	20.33
2.6	15.28	15.04
3.9	10.15	10.11

Regarding the boundary, the approximate boundary is used in the ANSYS simulation process. There are two ways to give the approximate boundary: the first is to replace the boundary potential with zero potential when the abnormal body exists, and the boundary needs to be made large enough so that the potential value at the boundary is considered to be very small and approximately equal to zero; Now, the following model is established to discuss the boundary problem. the power supply electrode ab/2 remains unchanged with a size of 100m, the receiving electrode MN=5m, and the abnormal body is a high-resistance karst cave with a resistivity of 30000Ω·m and the bedrock

resistivity of 1000 Ω m. Figure 1 is the calculated result curve of the first type of boundary.

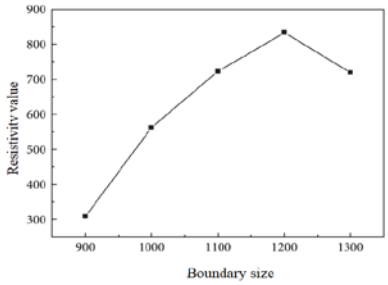

Fig.1 The Result Curve of the First Kind of Boundary Calculation

The numerical calculation method based on variational principle and subdivision interpolation is finite element method. The method has the following steps in application: firstly, the boundary value problem solved by the variational principle is converted into a variational problem, and then the solution area is divided into regular grid elements with interconnected nodes, thus the variational problem is approximately discretized. The main research content and method of numerical simulation is to select different mathematical models for experimental research, and provide constraints from geology, geophysics, geochemistry and other aspects to limit the multiplicity of experimental results and make the experimental results approach the geological status quo. Sequential indication simulation and man-machine combination reprocessing are adopted. The sequential indicator simulation method can simulate complex anisotropic geological phenomena. For the type variables with different continuity distribution, different variation functions can be specified respectively, so as to establish anisotropic simulation image. In order to solve the wave equation in a limited area, the absorbing boundary must be treated, otherwise, the boundary reflection will appear. In the process of simulation, it is very important to choose the appropriate mesh density, the time of over dense calculation is too long, and the precision of over sparse calculation does not meet the requirements. In order to overcome the contradiction between the accuracy of grid size selection and the workload. There are obvious differences in the distribution of velocity, streamline and temperature of ore-forming fluid, dissolution and precipitation types and distribution areas of ore-forming elements in different tectonic environments. The mixed reaction of ore-forming fluid is one of the important mechanisms of ore-forming process.

4. Application of High Density Electrical Method

High density resistivity method is widely used in hydrological and engineering geological exploration. The high density electrical method is mainly used in dam stability evaluation, dam foundation seepage and dam crack detection to see good application effect. For example, high density electrical method can be used for dam stability evaluation and dam foundation seepage detection, and can be used for detecting the fluctuation of the bedrock surface of the power station dam, for highway viaducts, site selection of high-rise buildings, detection of caves and culverts, geotechnical engineering investigation to determine the distribution and depth of lake rivers and catacombs, etc.

High-density transient Rayleigh wave method is used to complete geotechnical engineering investigation to determine the distribution and depth of ancient rivers, catacombs and caves and to quickly classify the site types. In addition, underground water is searched, pipelines are detected, mined-out areas are identified, and geological disasters are investigated by high-density electrical engineering geophysical prospecting. The dike reinforcement project in the test area is mainly built on the foundation with riprap foundation, and the foundation structure belongs to the earth-rock mixed type. The direction of the water facing surface is mainly similar to the vertical masonry retaining wall, and the rear of the wall is artificial fill. In addition, the lower layer of artificial fill is mainly composed of silt, silt sandwiched with thin layer of silty fine sand and silt-containing fine sand layer. The Second West-East Gas Pipeline is a safe route for the supply of oil and natural gas in a country, with a total length of 4859km. With several branch lines, the total length of the

pipeline exceeds 7000km. It is undoubtedly a major key project. When using high density resistivity method, especially profile observation method, the advantages of electrical profile method and electrical sounding should be fully brought into play. The apparent resistivity contour map is similar to the analysis result of actual geoelectric profile. Through comprehensive analysis of different research documents, we find that the variables in the apparent resistivity contour map carry a lot of valuable information. During field work, a relatively flat area should be selected according to topography and geomorphology. Two measuring lines should be arranged in a direction approximately perpendicular to NNE. The lengths of the two lateral lines are 500 meters. The distance A between the two electrodes is set to 5 meters, the point distance is set to 5 meters, and the electrodes are set to 101. The test depth is set at 1A ~ 33A, and the device adopts Winnell.

The inversion result graph curve shows a typical horizontal distribution of resistivity from high to low, with little fluctuation. Based on the riprap resistivity test and relevant geological data in the work area, analysis is made. The field data acquisition of high density electrical method includes electrode system, multi-core cable, multi-channel electrode converter and measuring host. According to the design of equidistant electrodes with a certain interval, the multi-core cable is connected to the host computer through a converter to realize the whole process of computer automatic control such as data acquisition, storage and transmission. We can know that the area between 320 and 350 meters in the section has abnormal resistance, with a width of about 30 meters, vertical development and low resistivity grade. The abnormal vertical depth of the resistance exceeds 100m. Resistivity shows obvious distribution characteristics of high and low layers, and the dividing line between high and low resistance fluctuates greatly. According to the analysis of geological exploration data of the dam, it is found that the apparent resistivity of the first layer with high resistance exceeds 200, with obvious closed circle, which is mainly generated by the concrete layer of the dam. Under the complex terrain conditions in the survey area, the fluctuating height difference and poor working conditions all affect the physical detection accuracy to some extent. To correctly divide the missing range of red clay, the relationship between high resistance anomaly and red clay missing, and the relationship between low resistance anomaly and red clay distribution must be clarified. Analysis and calculation. For example, we set the division basis of riprap and fill as 30-40Ω. m, and set the division basis of fill, silt, silt with thin layer of silty fine sand and silt-containing fine sand layer as less than l0Ω. m. After analysis and calculation, it is known that the thickness of masonry layer is about 6. 0m, and the thickness of filling soil is about 2. 0m, and silt, silt mixed with thin layer of silty fine sand or silt medium fine sand layer are below-4. 0m elevation.

In geological engineering exploration, high density resistivity method has certain advantages. High density resistivity method has the functions of profiling and bathymetry. According to the investigation of karst geology, it can vividly reflect the shape and occurrence of some electrical anomalies. The arrangement and selection of electrode devices include dipole and Wenner devices (α) with combination of two poles, three poles and four poles. The electrode distance selection is based on the buried depth of geological objects and target layers to ensure the optimal electrode number and electrode distance within the range of effective exploration depth. Influenced by atmospheric precipitation, it is also laterally replenished with surface runoff, and the underground water level changes with seasons and the changes of surface water level nearby. With the rise of water level and the continuous expansion of leakage channels, the splayed shape expands continuously, and the apparent resistivity amplitude of the abnormal zones on both sides gradually decreases. According to our inference results, the staff determined the drilling location 330 meters from the A survey line, with a hole depth of 214.02 meters. After pumping test, Q = 6.35m3/h. Through the analysis of water quality, the test results fully meet the drinking water standard and the well meets the requirements of the entrusting party. High density resistivity method can accurately locate the distribution and depth of groundwater. Some scholars have also combined the high density electrical method with the transient Rayleigh wave method to realize geotechnical detection in highway tunnel engineering. In archaeology, some scholars have used high-density electrical method to find out the distribution of ancient river courses, underground cultural relics and karst caves, and have received good results.

5. Conclusion

In this paper, the main advantages of high-density resistivity method are comprehensively analyzed, and several examples are used for discussion. By analyzing inversion maps of different cases, we find that high-density resistivity method can extract geological parameters and electrical distribution information of the detection area from profile and section inversion chromatograms. High density electrical method is an advanced electrical prospecting method. Relying on advanced technical support, it can effectively reduce the occurrence rate of electromagnetic interference and faults, greatly improve the working efficiency, and can carry out automatic acquisition during operation. Compared with conventional electrical method, high density electrical method is advanced in terms of method and data processing and interpretation. Engineering geological survey is generally aimed at understanding the distribution of foundation geology, rock and soil mass, culvert body and geological structure. With the continuous development and progress of science and technology, high density resistivity method should also actively combine with the current advanced science and technology, continuously improve and continuously develop, so as to better guide all kinds of engineering field exploration work.

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