Electromagnetic Response Characteristics Research on Mine Different Geological Body

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Electromagnetic Response Characteristics Research on Mine Different Geological Body

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ABSTRACT. A large number of experimental research of the mine transient electromagnetic method was used to collect typical geological anomaly experience card cases in Jin Cheng mine, such as structure, mined-out area etc. In order to achieve fine detection to geologic abnormal body, some card cases were analyzed by the electromagnetic response multi-parameter curves to identify electromagnetic response characteristics of different geologic abnormal body; Another card cases were showed all kinds of the visualization figures distinguished easily to distribution and characteristics of explain geologic abnormal body, such as structure, the mine mined-out area and contains water etc. The results show that: if there was the overall relatively low potential value, high apparent resistivity value, and the potential and apparent resistivity curves appeared to jump ups and downs, it was the typical electrical identification characteristics of no water bearing structure or goaf; If there was the overall relatively high potential value, low apparent resistivity value, and potential and apparent resistivity curve was smooth attenuation, and the inversion depth was smaller than the normal strata, it was a typical electrical characteristics of water bearing structure or goaf.

1. Introduction
In recent years, the refined detection of geophysical technology suited for the coal mine had been paid more and more attention. Not only they inherit the advanced geophysical techniques, they can be applied to the various underground environment. The detection technology can predict the geological abnormal body in front of excavation face and in the working face in time before mining, which can minimize losses caused by disasters and ensure the safety of mining[1]. At present, transient electromagnetic method is the main geophysical technology which can detect almost all kinds of water bodies, structure and goaf, and detection without dead angle in the full range of the roof and floor of working face and roadway, roadway sides and in front of heading face. Based on the detection cases, analyzing the electric field characteristics of transient electromagnetic method and summarizing the application results of different geological anomaly detection can provide reference experience for refined exploration of the future mine transient electromagnetic method.
2. Mine Transient Electromagnetic Method and Technology
Mine transient electromagnetic method belongs to the electrical exploration, which is a geophysical exploration method. It uses special equipment to observe and study the changes and distribution of geophysical field in mine according to the differences of electrical properties, such as electrochemical activity, conductivity, dielectric properties of coal seam, rock, water, goaf and all kinds of geological structure. Then finding out geological structure and achieving the purpose of coal mine safety [2].

Mine transient electromagnetic method general design four advanced detection direction (as shown in Figure 1 (a)), which include three transverse direction detection (45° angle with the roof of the roadway to the front of the roof detection, along the rock direction to the front detection, and 45° angle with the floor of the roadway to the front floor detection) and one longitudinal direction detection. Each lateral horizontal detection direction arranges14 detection angles (as shown in Figure 1 (b)), respectively, is on the left wall (180°, 165°, 150°, 135°, 120°, 105°), the front (90°, 90°), the right wall (0°, 15°, 30°, 45°, 60°, 75°). Three horizontal detection direction decorate a total of 42 angles. Longitudinal detection direction arrangement angle of 13 (as shown in Figure 1 (c)), respectively is the roof (90°, 75°, 60°, 45°, 30°, 15°), the front (0°), the base plate (-15°, -30°, -45°, -60°, -75°, -90°).

![Figure 1. Transient electromagnetic method to detect the direction and angle diagram](image)

3. Study on the Electrical Response Characteristics of Structures
The characteristics of electric field response of collapse pillars, faults and other structures are determined by the nature of the structure, the width of fracture zone, the degree of cementation, water features and dike intrusion. In general, the new fault resistivity value is low, the older the fault is, the stronger the cementing degree is, and the higher the resistivity value is. When the fracture zone is width or resistivity is obviously different from the resistivity on both sides, the resistivity is higher or lower, the fracture zone is wider and more broken, the resistivity is more different from the normal rock layer. When the water body exists in the structure, the water resistivity is higher, but the resistivity is lower, as the humidity or saturation of the rock increases, the resistivity dropped sharply. However, the resistivity of different rocks with the same water content may vary widely, due to the different mineralization degree of water. Generally, the dikes are invaded to form a good water-resisting layer, and the resistivity of the dikes is higher than normal coal, so it is generally high resistivity.

3.1 Non-water Structure
Taking the typical advanced detection results of non-water structure in No.15 coal seam of Jincheng Anthracite Mining Group for example. The typical response curves of the multi-electric field parameters are shown in Figure 2. Three typical data points are selected (blue line angle is 180°, red line angle is 75°, black line angle is 75°) to analyze the response characteristics of multi-electric field parameters. Figure 2 (a) was the potential-time curve, Figure 2 (b) was the apparent resistivity-time...
curve, and Figure 2 (c) was the apparent resistivity-depth curve. It can be seen from Figure 2 that the curves of Figure 2 (a) and Figure 2 (b) of the three data points almost coincided before 0.2 ms, indicating that the field was in the primary field response curve of the detection; The curves of Figure 2 (a) and Figure 2 (b) showed obvious deviations between 0.2 ms ~ 4 ms, the three lines are nearly parallel, the blue line potential is relatively large, the apparent resistivity is relatively low, and attenuation is more smooth, the black line was relative to the center, the attenuation is more smooth, the red line potential is relatively low, the apparent resistivity was relatively high, there were two large ups and downs in the attenuation process, the time-depth measurement was carried out to form the apparent resistivity-depth curve (Figure 2 (c)), after the conversion the depth was about 20 m ~ 120 m or so, the reaction is more obvious, The maximum apparent resistivity of the red line which was high apparent resistivity anomaly was more than 1000 Ω·m, and there were two ups and downs, The apparent resistivity value of the black line which was the normal rock layer resistance was between 100 Ω·m ~ 1000 Ω·m, the apparent resistivity of the blue line which was a low apparent resistivity anomaly was the lowest, and the whole was below 100 Ω·m, this region of the true reflection of the formation or structure of electrical information differences; The curves of Figure 2 (a) and Figure 2 (b) showed a significant cross-jump change, and no obvious rule could be followed, indicating that this segment was affected by other electromagnetic field disturbances, so it could not truly reflect the formation geoelectric information.

Figure 2. Typical response curves of non-water structure electric field

Figure 3. Typical non-aqueous structure apparent resistivity section

It is more intuitive to see the difference of the electric field characteristics at different angles by time-depth conversion into a graph of the angle data from 0.2 ms to 4 ms in this direction. In the apparent resistivity section of Figure 3, the high-resistance anomaly 1 (represented by the red) was obvious double-ring-shaped high impedance, and the whole resistance value is higher than that of the two sides, inferred that there are at least two non-water-bearing structures here; Two low-resistance anomaly (represented by the blue): low resistance anomaly 1 and low resistance anomaly 2, which are the overall relative low resistance, and close symmetrical distribution to the two groups of roadway,
inferred for the anchor network effect in roadway's sides; The normal strata is represented by green and yellow areas in the figure. In the block diagram of apparent resistivity in Figure 4, it is also possible to stereoscopically see the intermediate high-resistance bulge portion, and make a sharp electrical contrast to the low-resistance regions on both sides. The front closed loop of high-resistance anomaly 1 of Figure 3 revealed the non-water collapse column, and the rear closed loop is exposed as non-water fault. From the three transversal detection stereograms of Figure 5, it can be seen that the non-water collapse column extends from the floor plate 45° through the bedding direction, then to the direction of 45° in the roof, extension, the development range of subsided collapse column reduces gradually, which accords with the developmental form of collapse column.

Figure 5. three-dimensional detection results

3.2 Water-bearing Structure

Taking typical advanced detection of water-bearing structure in No.3 coal seam of Jincheng Anthracite Mining Group for example. Figure 6 shows the apparent resistivity-depth curve of a typical survey point (blue line angle was 90°, black line angle was 105°) and the electric field response characteristic is analyzed. It can be seen from the figure the section of 15 m ~120 m is the reflect the apparent resistivity attenuation of true rock layer, two curves near to be parallel, and the distance is far, the apparent resistivity is relatively normal of black line, the average apparent resistivity is about 60 Ω·m and the depth is about 120 m. The apparent resistivity of blue line is relatively low, the curve attenuation is smooth, the average apparent resistivity is about 30 Ω·m, and the depth of detection is only about 70 m.

The apparent resistivity inversion section of all detection points is shown in Figure 7. The blue line shows the distribution range of low-resistance anomaly which locates in the right of detection zone. The area is large and forms a closed-loop. The whole apparent resistivity is relatively low, asymmetric, and there is no significant iron and other interference in the scene. It infers that the low-resistivity anomaly 1 is water-bearing structure according to geological data and scene situation. The black line shows normal rock layer, which is located in the left side of the figure, the apparent resistivity contour was attenuated evenly, it can also be seen from Figure 8 that there is a closed-loop low-resistance anomaly ahead of the head, which corresponds to Figure 7. The block diagram of apparent resistivity is shown in Figure 9. It is also possible to visually see the low-resistance depression in the right side, which is in sharp contrast to the normal coal-rock mass on the left. After the mine verification, it is about 20 m drilling in front of the water, turbidity, water pressure of about 1MPa, water yield of
7.2~6.4 m³/h, anchor water phenomenon, the main water bodies are tectonic water formed by the sandstone water bodies through the collapse column (Figure 10) after water quality testing and drilling perspective analysis. Normally, when the underground karst cave develops to a certain degree, the upper part of the subsidence collapse under the reflection of multiple geological factors. The edge of collapse column exists fracture plane which often is rough and uneven. The fracture surface makes the stratum produce remarkable relative displacement and destroy the integrity and continuity of the strata. The fillings which are composed of the dissolved debris, clastic material and clay are loose and usually have high porosity. It may become a strong permeability water channel and has a certain water content. Its resistivity was lower than the rock resistivity. Therefore, due to the karst collapse column, the electric field response characteristics usually show low resistance anomaly.

Figure 7. Horizontal apparent resistivity section of aqueous structure

Figure 8. Longitudinal apparent resistivity section

Figure 9. The block diagram of apparent resistivity

Figure 10. Bedding apparent resistivity

4. Study on Electrical Response Characteristics of Goaf

The electric field response of goaf and overburden failure zone is affected by the water content of the overlying fissure zone, it is manifested in that when the fractured zone is saturated with water, the resistivity of the goaf will decrease, when the fractured zone has not water, the resistivity of the goaf will increase greatly, the extent of decrease or increase was closely related to the degree of water cut and the damage degree. In the intact strata, due to the structure has not basic variation, the electrical characteristics is less affected by the mining, but due to the destruction of the rock and the volume of expansion, if the close water body is not immersed in the fracture zone, the resistivity of the mined-out area should be higher than that of the non-destructed area, if the water body is immersed in the fracture zone, because the rock cracked in the water, its conductivity became enhancement, the resistivity of the rock should be much lower than that of the non-destroyed. Most of the mines in
Jincheng Mining Area are not under pressure exploitation, and the influence of confined water is small, so it has little influence on the electrical characteristics of rock mass, which is mainly affected by the water body of overlying fractured zone.

4.1 Mined-out Area with Water

Taking detection to the mined-out area and water condition in some coal group 3’s digging roadway of Jincheng Anthracite Mining Group for example, three coal mine surveying lines of mine transient electromagnetic method are designed, the survey line length is 310m and the dot pitch is 10m with every line layout of 32 points. The detection directions are the roof 45° direction, along the 0° direction, bottom plate 45° direction (Figure 11). Figure 12 is the line-level curve of the potential-time curve, it measures for the secondary field potential decay curve between 2 ms ~ 100 ms, the curve decay is more smooth with no obvious tail jump branch point, indicating no significant iron and other interference site, and all the curves were nearly parallel, but there is a significant deviation, forming two distinct beam separation: 1-15 point blue wire harness and 16-32 point black wire harness, the relative potential value of the blue wire bundle is obviously larger than that of the black wire harness, and the apparent resistivity-depth curve is formed after all the measuring points of the line were time-depth conversion (Figure 13), the difference reflected more obvious after the conversion depth of 20 m ~ 130 m or so, there is no overlap between the blue harness and the black harness, the apparent resistivity of the blue wire harness is relatively low, with an average of 4.5 Ω·m, which is obviously low resistance anomaly, the apparent resistivity of the black wire harness is about 10 Ω·m, which was the relative normal rock mass resistivity value.

Figure 11. Layout of roadway Line     Figure 12. Bedding potential-time curve     Figure 13. Bedding apparent resistivity-depth curve

In the section of the apparent resistivity profile in Figure 14, the low-resistance anomaly distribution of the blue wire harness was large, and it forms a sheet of low resistance anomaly between the points 16-32 (distance was 150 m-320 m), the apparent resistivity value is relatively low, asymmetrical, and the apparent resistivity value of the area between 1-15 points (distance was 0 m-150 m) represented by the black wire harness is quite different, and there is no visible iron and other interference, it is inferred that the low resistance anomaly 1 may be 3 coal mined-out area water through the combination of geological data and on-site analysis, which was water-rich, while the black
line represents the normal rock. In the apparent resistivity profile of Figure 15, the right blue low-resistance depression can also be seen in stereo and visual contrasted with the green normal coal-rock body on the left. After drilling by the miners, it is verified the original small coal mines 3 mined-out area, and drilled a larger amount of water, which has a total of 800,000 m³ water.

4.2 Complex Goaf Area
Taking typical advanced detection results to complex goaf area in some coal group 3’s of Jincheng Anthracite Mining Group for example, Figure 16 shows the multi-electric field parameter response curve, three typical data lines (blue line angle of 45 °, red line angle of 135 ° and black line angle of 120 °) are selected to analyze the response characteristics of multiple electric field parameters. It can be seen that Figure 16 was similar to the multi-electric field parametric curve of Figure 2, the pre-field is the primary field and the late field is obviously disturbed by other electromagnetic fields. The effective secondary field of induction was mainly between 0.1 ms ~ 3.5 ms, there are obvious deviations in the segment area curves of Figure 16(a) and Figure 16 (b), the three lines don’t cross, the blue line potential value is relatively large, the apparent resistivity is relatively low, and the attenuation is smoother, the black line is relatively centered, the attenuation was smoother, the potential value of the red line is relatively low, the apparent resistivity is relatively high, but it is not as obvious as in Figure 2, and the fluctuation is large during the decaying process, the time measurement points for the time-depth conversion to form the apparent resistivity depth curve (Figure 2 (c)), the inversion depth is about 10 m ~ 100 m. the red line is entirely located above the black line, the apparent resistivity is slightly higher, especially at the depth of 50 m ~90 m, the more obvious, high impedance anomaly, the apparent resistivity of black line is between 10 Ω·m and 100 Ω·m, which is the normal rock layer resistance, the blue line apparent resistivity is the lowest, and the whole is below 10 Ω·m, which is a low resistance anomaly, this section area truly reflects the apparent information of the electrical conductivity of the stratum or goaf.

Figure 16. A typical measuring point curve in 0 ° direction
The time-depth conversion of the data at all angles of 0.1 ms to 3.5 ms in this direction shows that the difference in electric field characteristics is more intuitive, in the apparent resistivity section of Figure 17, it is found that the obviously closed-ring high impedance abnormal area is near the high-resistance anomaly 1, which is represented by the red line, and the whole resistance value was higher than that of the two sides, it is inferred that the original small coal mined-out area without water, the blue line represented two low-resistance anomalies: the low-resistance anomaly 1 and the low-resistance anomaly 2, the overall relative resistance are low, the asymmetric distribution, and site has no anchor interference effect, it is inferred two low resistance anomaly for the original small coal mines in mined-area water, the black line in the green and yellow areas of the figure represented the normal rock layer. After drilling the driller verification, it can be seen the air in front of 50 m, through the drilling perspective, it is a small coal mine tunnel, with no water, then back 30m, it is to the right to help drill, it hit the depth of 35 m case of air, with water larger, according to the drilling results and the miners to provide information, it is delineated generally the original small coal mined-out area.
distribution range, and it is basically consistent to the delineated scope of detection results, as shown in Figure 18.

![Figure 17. Bedding apparent resistivity section](image1)

![Figure 18. Distribution of mined-out area and bedding detection results](image2)

5. Conclusions and Recommendations

In order to predict the geologic abnormal body exactly, such as the geologic structure, mined-out area and water body, the mine transient electromagnetic method is used for much of experimental research in Jincheng diggings. This paper collects typical cases of geological anomaly experience, identifies electromagnetic response characteristics of different geologic abnormal body and forms all kinds of visual maps to distinguish easily through analyzing the multi-parameter curves of electromagnetic response. The visual maps explain the distribution and characteristics of geologic abnormal body which achieve the object of refined detection. Through the above analysis, it draws the following conclusions:

1. For the non-water structure, the overall potential value is relatively low, the apparent resistivity value is relatively high, and the potential and apparent resistivity curve reflects non-aqueous structure obviously, the curve sharp jumps up and down, which is typical electrical characteristics to identify the non-aqueous structure;

2. For the water-bearing structure, the overall potential value is relatively high, the apparent resistivity value is relatively low, the potential and apparent resistivity curve has a smooth attenuation, the depth of inversion is lighter than the normal rock depth, the electrical response characteristics is similar to the characteristics of the electrical response of iron interference, such as bolt-net. If the iron disturbance has been eliminated, it will be easier to identify the water-bearing structure.

3. For the water-containing goaf area, the overall potential value is relatively high and the apparent potential value is relatively low. The characteristic points of typical response curve increases greatly with the enlargement of the distribution of the water-bearing goaf and has a distribution of bunch shape, which is a typical feature of the identification of water-bearing goaf areas;

4. For non-water goaf area, the overall potential value is relatively low, the apparent resistivity value is relatively high, and the local curve has a strong jump. With the enlargement of the distribution area of the non-water goaf area, the number of jumping points increases, and has a distribution of bunch shape, which is easy to identify.

The analysis of response characteristics of all kinds of geological abnormalities neither taking into account the influence of on-site iron, electric power, hydraulic and other interference conditions on the response curve, nor taking into account the influence of different parameters of the instrument and software on the response curve. Therefore, the experimental work should be increased in this area of research, with a view to be more realistic conditions.

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