Atlantis Highlights in Engineering, volume 5
International Conference on Precision Machining, Non-Traditional Machining and Intelligent Manufacturing (PNTIM 2019)

Application Research of Mine Detection Technology with Transient Electro-Magnetic Method

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***Abstract*—Different rocks have different conduction; common coal measure rocks show different resistivity values. In general, the resistivity values of mudstone, siltstone and medium-coarse sandstone increase continuously, and the lithological changes in the vertical direction show as the increase or decrease of resistivity. The lithology changes with the direction of formation are generally small and the resistivity is uniform. When the coal measures are stable, the variation rule of vertical resistivity is basically the same, and the electrical conductivity is relatively balanced in the direction of bedding. When there are water-filled cracks in the coal measures sandstone, or when the fracture zone is cut by a fault, the good conductivity of the water body leads to obvious electrical difference between the structure and the surrounding rock. Based on the existing detection technology research, on the basis of Hydro geological data of limestone aquifers of the Buliangou mining field of Inner Mongolia, the transient electromagnetic method (TEM) is adopted to the mining face detection inside the top, bottom water condition, and get satisfactory results, it provides a solid foundation for mining design and waterproofing.**

Keyword-TEM; Mining Face; Bottom Board; Detect

I. Introduction

In order to speed up the coal field development and construction, promote local economic development, and make energy advantages into economic advantages, and improve the level of local material culture, from, Xi'an Research Institute of China Coal Technology & Engineering Group to work up for Inner Mongolia's Buliangou coal Co., LTD. to find out the field within the mining area coal seam working face roof within 0 ~ 100 m, 0 ~ 80 m, the lateral 50m of geological structure, the rich water area as well as the hydraulic relationship between detection, for the working face, water conservancy project prevention provide reference for the design and implementation of data.

According to the characteristics of the geological structure of the well field, the YT120(A) explosion-proof audio electric perspective detector is adopted after comparative multiple methods. The electric signal is transmitted to the formation by the motor at a certain frequency, and the equal frequency signal is received by the receiver in a certain area. The instrument adopts the form of safety and explosion-proof, the power supply machine has the function of quick over-current protection, the measurement accuracy is high, the anti-interference ability is strong, and it is suitable for the water-rich exploration and evaluation of coal measure.

II. Geological Survey and Characteristics

A. Geology and Structure of Mine Field

The tectonic structure of the Junggar Basin coalfield belongs to the northeast margin of the Ordos platform of the north China platform. Coal field structure is mainly caused by crustal movement, the tectonic form is mainly fold, and the fault structure is not developed.

Mengtai buliangou coal Located in the northernmost part of the Junggar Basin coalfield, the structure of the mine in Inner Mongolia is similar to that of the coalfield. It is Monocline structure with NNW and SWW trend. The formation of mining area is gentle; the dip Angle is generally 3 ° to 5 °. From the underground exposure, it can be seen that small and medium-sized fault structures in the mine field are relatively developed, and no collapsed column structure larger than 30m in diameter is found.

The height of the workface floor is + 830.5~ + 899.2 m, The western part of the workface is below the water level of limestone, and the interface between the coal floor and the Ordovician limestone top is about 55 m, most of which belongs to the mining with pressure. The excavation of the detection working face revealed nearly 35 faults of different sizes, with a maximum distance of 6.2m. Because of the imbalance of water-rich aquifers, the development of Karst water resources is strong. It is possible for limestone water to be discharged into coal seams through vertical water structures and weak water layers.

B. Hydrological Characteristics

Magmatic rocks intrude in the northeast and southwest part of the mining area. Karst water in this area is supplied by meteoric precipitation in exposed limestone areas on the east bank of the Yellow River, lateral leakage of the Yellow River, and exposed and covered limestone areas. Run off from northeast to southwest. According to the regional information and limestone aquifer hydro geological data already in the field, not even the ditch of mining field limestone water level + 871.69 ~ + 871.91m, accumulated in the process of excavation revealed six collapse column, detected face with adjacent face in the excavation process of the communist party of China 14 faults of different size, among them, the transport gateway 322 meters of the fault in the process of exploration to the exploration of roof and floor with water, roof drilling water yield up to 19m^3/h, bottom hole water yield of 10.9 m3 / h, no significant decline in water in nine days. It is judged as limestone water in fault communication.

The water source directly filling the roof of the detection workface is the fractured sandstone water of Shanxi formation, which is blocked by the water-proof layer of mudstone below the lower stone box formation. When workface is mined, the fracture zone usually develops to the height range of 10~20 times of the thickness of the coal seam above the roof, which may form a water channel. The water-rich water of the coal roof sandstone aquifer and other indirect water-filled aquifers in this range are all weakly water-rich, but the water-rich is extremely uneven.

C. Survey of Workface

The detection workface is located in the middle and west of the mining area, with 6# coal return air roadway in the east, F6206 workface in the north, mine field boundary in the west, and un-mined area in the south. Surface 6 coal floor elevation +830.5 ~ +899.2m, relative height difference 68.7m, east high west low. The buried depth of the coal seam is 314.55 ~ 328.71m, with deep west and shallow east. The strike length of the workface is 2047.5m, the mining width is 240.30m and the area is 492950m2. Coal 6 in the workface has a thickness of 12.30 ~ 22.85m, an average of 17.68m, and a dip Angle of 0 ~ ±15 °. The occurrence of coal seam in the workface is relatively stable. The structure of coal seam is complex, containing 5 ~ 8 layers of gangue, which are mostly concentrated in the middle and lower part of coal seam.

To sum up, this mining area belongs to a relatively complex geological structure. Before mining, it is necessary to use geophysical prospecting to detect the water-rich condition of the working face's inner roof and bottom plate. Through comprehensive research, the distribution of water-rich anomalies in the aquifer within 100m of the top face of the working face was determined by tem. The abnormal areas rich in water are distributed within 50 meters of the workface.

III. KEY DETECTION TECHNOLOGY

Different rocks have different electrical conductivity and common rocks in coal measures have different resistivity values. In general, the resistivity values of mudstone, siltstone and medium grit sandstone increased successively, and the lithologic changes of coal measures in the vertical direction showed that the resistivity increased or decreased. Lithologic changes along the formation direction are generally small, and the resistivity is relatively uniform. When the coal measure is stable, the variation law of vertical resistivity is basically the same, and the conductivity is relatively balanced in the direction of bedding. When there are water-filled cracks in the coal measure sandstone, or the water cut by fault leads to the water cut in the broken zone, due to the good conductivity of the water, the structure and surrounding rock have obvious electrical differences.

A. Transient Electromagnetic Method

According to the difference of rock conductivity, the transient electromagnetic method USES the impulse current as the field source to stimulate the detection object to induce the secondary current, and measures the response of the secondary field with time in the pulse gap, so as to understand the electrical change of the underground medium.

When exploring underground geologic bodies, a pulse current of a certain frequency is applied in the middle of the return line to a region around the sent return line to produce a stable magnetic field (called the home field or excitation field) for a period of time. If the primary current is suddenly cut off (that is, the pulse gap), the main magnetic field disappears, causing the induced electromotive force to be generated in the well-oriented geological body in the magnetic field due to the change of magnetic flux and the formation of secondary eddy current field in the well-conductive geological body. Due to the joule heat loss, the secondary eddy current is constantly decreasing. The second field also decays. Because the attenuation of induced secondary field is related to the conductivity of underground geological body, the better the conductivity is, the slower the attenuation of secondary field is. The worse the conductivity, the faster the secondary field decays. Therefore, by analyzing the attenuation law of the secondary field, the purpose of detecting underground geological anomalies can be realized.

The principle of mine field tem is the same as that of ground tem. The difference is that mine tem is carried out in the limited space of underground roadway. The transient electromagnetic field is distributed in a complete space, and the whole space effect becomes an inherent problem of them. In the case of transient electromagnetic exploration in the mine, according to the exploration task, the coil can be placed in the roadway floor, roof or the area of water-bearing abnormal body within a certain depth. Full space electromagnetic induction current loop diffusion is shown in figure 2.

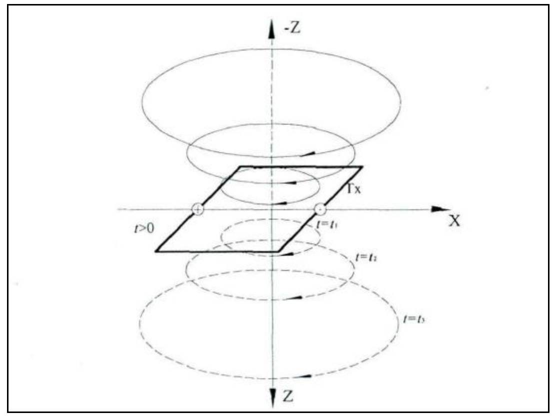

Figure 1. Diagram of full-space induction current ring diffusion

The multi-turn overlapping loop device is generally adopted in the field transient electromagnetic exploration. The overlapping loop device has simple response curve shape, high reception level, good penetration depth and anomaly analysis and interpretation.

B. Detection Instrument and Parameter Setting

YCS2000 mine transient electromagnetic instrument is used in this mine exploration, which is applicable to the dangerous environment of underground gas and coal dust explosion, and is used to detect the roof and floor of the working face and water-conducting structures in a certain range of driving. The main technical indicators are as follows.

1) Environmental conditions. Temperature: 0~+40˚C; Relative humidity: ≤95%(+25˚C); atmospheric pressure：86kPa~106kPa.

2) Launch some indicators. Transmitting signal: bipolar square wave; Transmission frequency: 2.5Hz, 6.25Hz, 12.5Hz, 25Hz, Maximum emission current: 3A; Maximum emission voltage: 6.5V.

3) Receiving part index. received signal：sine wave，Receive the voltage: ≤5V（peak value）, dynamic range:130dB（incoming frequency325Hz）, Restrain power frequency：no less than75dB（incoming frequency 50Hz, 1V(peak value); Repeated measurement error：no less than 0.1%（Valid input value 100mV, 325Hz sine wave）.

C. Design of Detection Experimental Parameter

Due to the strong directivity of transient electromagnetic, the water-rich property of the roof and the outer side of the detection roadway is designed as follows: within the scope of 100m of the roof of the working face, 3 angles are designed for collection, the vertical roof is 90° upward, and the collection is 30°, 60° and 90° inward respectively. The range of 50m outside the workface is designed to collect 0° and 30° above. The transmitting line width is 2*2m, the receiving line is magnetic probe, and the sampling frequency is 25Hz.

D. Analysis of the Experimental Results

According to the actual situation of the detection working surface, the effective distance of 100m needs to be detected. The purpose of the test is to check whether the instrument and device parameters adopted can meet the required effective distance. According to the empirical formula (1) of detection depth:

$$d = 503\sqrt{\rho t} \quad (1)$$

Where, ρ is rock resistivity, and t is the time of transient sampling.

In order to reach the detection depth, YCS2000 instrument and the above supporting parameters were adopted, and the experimental curve obtained was shown in figure 2.

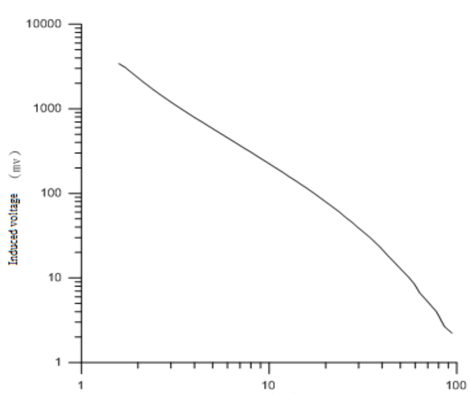

Figure 2. Experimental curve of transient electromagnetic method

In the experimental curve, effective signals can be collected within 100ms. According to the empirical detection depth formula and resistivity value of coal strata, this device can detect the required depth.

IV. Detection Applications

This specific construction is divided into two roadways, which are: the distance between the auxiliary transportation channel and the cutting hole of the working face is 2,100m, the distance between the transportation channel and the cutting hole of the working face is 2,100m, and the distance between the geophysical detection points is 10m. Transient electromagnetic method actually collects 5 azimuth data: the range of working face roof is 100m, and the design collects 3 angles. The vertical roof is 90° upward, and the vertical roof is 30°, 60° and 90° inward respectively. In the range of 50m on the north side of the working face, two angles are designed and collected. The bedding is 0°, 0° and 30° above, respectively, and 444 physical points are collected.

Transient electromagnetic data processing software is used in mine. The latest technology and methods are adopted in recent years. It has a good human-computer interaction interface, high degree of automation, easy to operate and high accuracy of processing results. The software package adopts a modular structure, and each module can independently perform different functions and process different stages of data.

A. Transient Electromagnetic Image of Roof

According to the above studies and experiments, the low-resistivity abnormal sections of different angles (90° included) above the auxiliary and main operating shunts of the working face were obtained, with the left side being the cut hole and the right side being the retreat, as shown in figure 3 and figure 4. The abscissa in the figure represents the distance from 0# point (retreat channel), and the ordinate represents the detection height. The lateral variation of resistivity is relatively balanced, which corresponds to the relatively stable deposition of coal-bearing strata. In the range of 25~40m and 70~90m on the roof of the coal seam, the lithology is mainly inter bedded with mud-sandstone.

Among them, the thickness of the sandstone layer varies greatly and the water-rich layer has obvious heterogeneity.

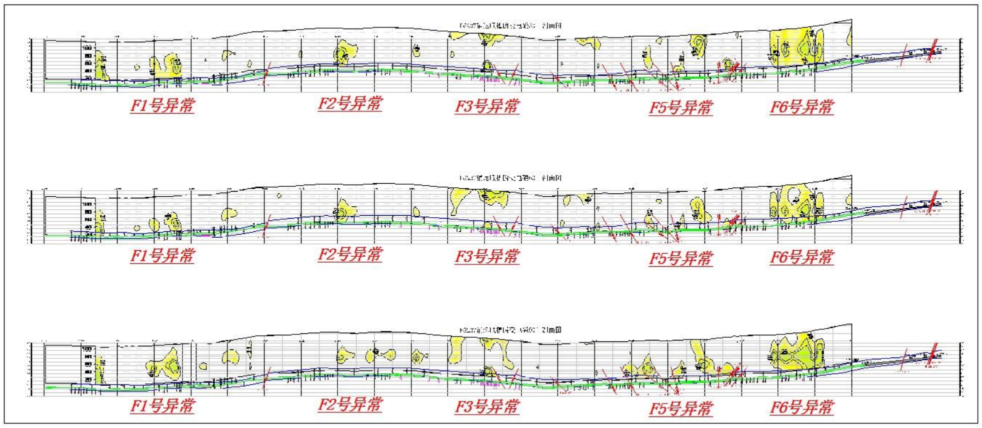

Figure 3. Diagram of different angles above the auxiliary transport gateway

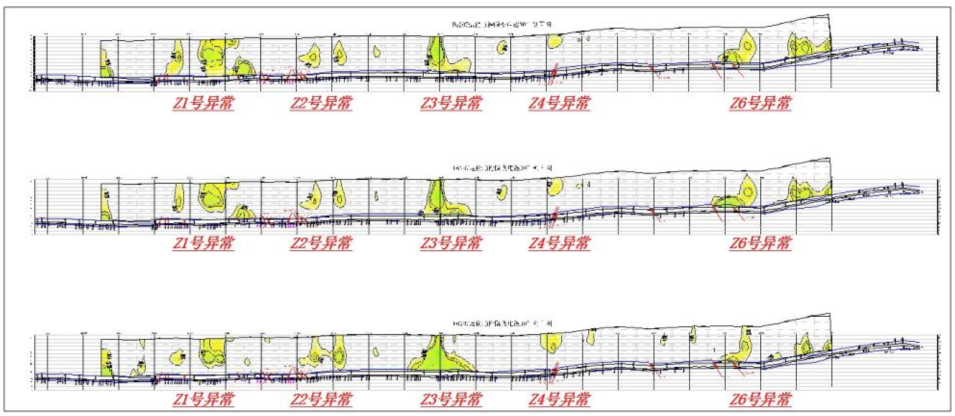

Figure 4. Diagram of different angles above the main transport gateway

The abnormal characteristics of variable electromagnetic low resistance are analyzed as follows

In the above five abnormal sections with low apparent resistivity, the abnormal strength of no. 6 abnormal area is relatively strong, the abnormal strength of no. 5 abnormal area is relatively weak, and the other abnormal strength is medium. The distribution range of no.6 abnormal area is relatively large, while that of no.1, 2, 3 and no.5 abnormal area is relatively small.

In the above five abnormal sections with low apparent resistivity, the abnormal strength in no. 1 and no. 3 is relatively strong, followed by no. 6 and no. 2 and no. 4. The abnormal distribution range of no. 1 and no. 6 abnormal areas is relatively large, while that of no. 2, 3 and 4 abnormal areas is relatively small.

B. Low Resistance Abnormal Diagram of Roof

According to the disclosure of hole Y1008 in the workface, the roof of the roadway in the middle of the workface is about 25m away from the coarse sandstone layer of the old roof and 70m away from the sandstone layer of the top of Shanxi formation. In order to explore the plane distribution pattern of the low-value abnormal area on the roof of the working face and the potential water-bearing passage, the plane anomaly diagram of the old roof sandstone layer around 25m on the roof of the working face is cut out, as shown in figure 5. The plane anomaly diagram of the corresponding sandstone layer on the top of the Shanxi formation around 70m on the roof is shown in figure 6.

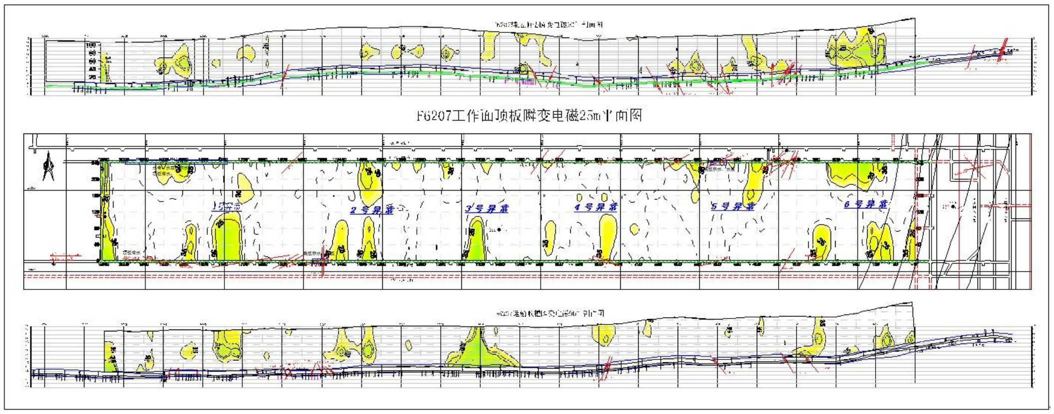

Figure 5. Plan of Low Resistance Anomaly Near 25m Rooftop

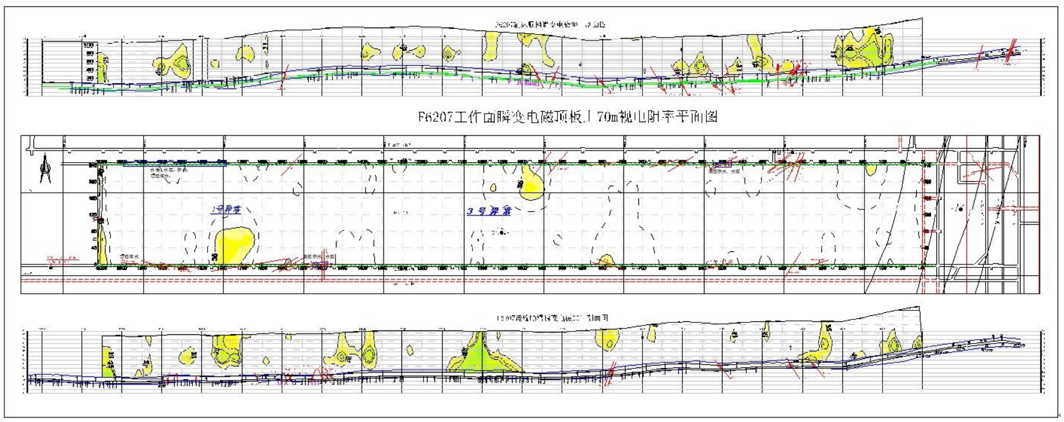

Figure 6. Plan of low resistance anomaly near 70m rooftop

According to the section drawing of three directions, the data are extracted and the low-resistivity abnormal trend plan of 25m and 70m on the roof of the roadway with grid difference is carried out. It can analyze the trend of water-rich anomaly on the top of the working face.

To sum up, it can be seen from the section drawing that the core part of the low-resistivity abnormal area above the working face roof is mainly concentrated in the range of 25~40m aquifer, and the geophysical anomalies are mainly concentrated in the vicinity of no. 1, 2, 3 and 6, indicating that the water-rich sandstone of the roof is unbalanced.

V. CONCLUSION

In this paper, based on TEM, through equipment technology research, parameter setting and detection point selection, the water-rich abnormal areas above the 2060m roof, under the floor and within 60m outside the working face were detected and studied, and the conclusions are as follows.

A. Delineated the Abnormal Area of the Roof

There are 5 abnormal areas of low apparent resistivity in the auxiliary transportation channel of working face. Among them, the intensity of F6 area is relatively strong and the distribution range is relatively large, while the intensity of F5 area is relatively weak and the rest is medium. The abnormal areas of F6, F1, F2, F3 and F5 have a small distribution range.

Five abnormal areas with low apparent resistivity values were found in the detection section of the main moving channel of the working face. The abnormal areas Z1 and Z3 are relatively strong, followed by Z6, and Z2 and Z4. Z1 and Z6 abnormal areas are relatively large, while Z2, Z3 and Z4 abnormal areas are relatively small.

B. Analyzed and Judged the Abnormal Properties

According to the detection results of TEM, combined with the analysis of the data of drainage drilling and hydrogeological data, the abnormal areas No. 1, 2 and 5 discovered by the roof detection revealed multiple faults along the channel, and it was judged that the area was caused by the development of structural fractures. The anomalies of No. 3, No. 4 and No. 6 were due to the thickening of the local sandstone aquifer and the strengthening of the water-rich aquifer.

C. Delineated the abnormal area of the lateral wall

Six relatively obvious low-resistivity abnormal zones were found outside the auxiliary shun channel, and the anomalies were mainly concentrated in the range of 30~60m. One relatively low-resistivity abnormal zone was found outside the main shun channel. The abnormal areas detected by the probe are thought to be relatively water-rich, resulting from local fractures caused by faults.

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