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Review of Electrical Prospecting Technology for Coal Mining in China

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Over the past few decades, shallow coal resources in China have nearly been mined out to meet the growing demand of industry. To address the challenge, there is great need to shift our focus from shallow to deep coal resources. However, water filled in deep Ordovician limestone and Taiyuan Group limestones strongly threaten the exploration of coal with due safety and environmental considerations such as mining subsidence and protection of groundwater resources safety of coal production. Two main factors i.e. to maximize the production in coal mining and protection of groundwater have focused our attention on the need for mapping the water filled zone and corresponding hydro geological conditions accurately in deep North China coal field which is of great guiding significance and practical value for coal mine safety. There are number of geophysical techniques which have been used in coal prospecting for many years. One of the modern geophysical methods is transient electromagnetic method (TEM).

The sensitivity for high conducting body, small volume effect and high work efficiency are the features making it preferred electromagnetic method in coal hydrogeological prospecting. To exploit coal reservoirs lying at greater and the subsequence increase of mining depth, it is necessary to utilize certain geophysical techniques having capability to look into deeper horizons of the subsurface.

Commonly, water-filled structures can be divided into five types:

- Aquifer at the quaternary bottom boundaries with a shallow buried depth;
- Hole and fissure water from sandstones at coal seam roof;
- Water from Ordovician limestone at coal floor;
- Water from water - conducting channels such as collapse columns and faults;
- Water from old mine goafs and poor sealing drilling holes.

Generally geophysical methods can be grouped in two main categories surface and subsurface geoph include direct current method (DC), TEM, and controlled source audio frequency magnetotelluric (CSAMT). Details of each geophysical tool in terms of its main characteristics and applications are listed as following (Table 1).

The main work involved in underground geophysical detection includes:

- Advanced detection of water hazard in front of tunnel.
- Water hazard in the top or bottom of coal seam.
- Lateral water hazard beside the outer tunnel boundaries.
- Small structures and collapse column in the coal seam.
- Test of grouting for water-bearing structures.
- Real-time monitoring on floor damage belts and water bursting. The electromagnetic methods can be used mainly include: Underground DC, and Underground TEM .The use of the DC methods is shown in Table 2.

There are many new trends of electrical methods in the field of coal mine, such as

- For hydrological hazards, the focus of work have transformed from previous detection gradually to monitoring, early warning and forecasting.
- Other advanced geophysical methods are introduced to this field, such as frequency-domain IP, nuclear magnetic resonance, seismic-electric advanced detecting technology, underground and ground joint geophysical method and mine seismic prospecting (MSP).

Methods	Characteristics	Main field of application
DC	1)Mature theory and technique, easy operation, anti-interference. 2) Large volume effect, and with the increase of prospecting depth, the resolution rapidly decline. 3) Large terrain effect, low work efficiency, and heavy workload	Mainly used for shallow (less than 500 meters) hydrologic prospecting such as, quaternary aquifer, overburden thickness, fault fracture zone, karst and mined-out area
TEM	1) Small volume effect, high lateral resolution, high work efficiency. 2) It can penetrate high resistance shielding layer and have a relative great prospecting depth. 3)Easy affected by humanities facilities. 4)Having blind areas for shallow investigation	Mainly used for middle-deep(less than 1000 meters) hydrologic investigation, such as water enriched area of sandstone, fault fracture, karst fissure and mined-out area
CSAMT	1) It can penetrate high resistance shielding layer and have a relative large prospecting depth. 2)High lateral resolution and high work efficiency 3) Easy affected by surface heterogeneous bodies (static effect). 4)Hard to make sure all signal belong to far filed 5)Relative complicated data processing and interpretation	Mainly used for middle-deep (about 2000 meters) hydrologic investigation, such as water enriched area of sandstone, fault fracture, karst fissure and geothermal resource
EH-4	1) It can penetrate high resistance shielding layer and have relative large prospecting depth. 2) High vertical and lateral resolution. 3) High work efficiency. 4) Easy affected in mine area.	Mainly used for middle-shallow(less than 800 meters hydrologic prospecting, such as water enriched area of sandstone, fault fracture, karst fissure and mined-out area.

Table 1: Ground electric techniques for detecting water hazards in coal mine.

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Methods	**Common configurations**	**Main field of application**
Electrical sounding on tunnel roof and floor	1) fixed M,N method (Schlumberger array); 2) Wenner array; 3)Three point electrode array	Detect insidious water flowing fractured zone, abnormal water enriched zone, thickness of the aquifer, thickness of the aquiclude in the roof and floor rock of the coal seam.
Tunnel high-density electrical method	1)Wenner symmetrical four electrode array; 2) Wenner dipole array; 3) Wenner differential array; 4)Wenner three electrode array	Detect water-bearing structure of the floor, evaluate the rock aquosity, divide the aquifer and aquiclude of floor, and investigate the development of limestone karst
Audio frequency electrical penetration method	Fixed point three electrode electrical penetration method	Detect small structures in the working face; detect water-bearing structures and water-conducting structures in the roof and floor rock of working face.
3D electrical method	1)AM array; 2) ABM array.	Tunnel 3D resistivity prospecting, monitor geoelectric field, deformation and failure of surrounding rock, coal mine disaster forecast.

Table 2: Comparison of underground electrical methods.