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Study on Measuring and Forecasting of Fully Mechanized Working Face Roof Pressure System

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Abstract

China is one of the largest coal producer and consumer countries in the world. However, due to the complexity of coal resources, storage conditions, geological disaster-prone coal mines, it is also a coal mine accidents multiple country, coal mine accidents and deaths of China accounted to about 80% total of the world. In the coal mine accident occurred, roof accident has accounted for around 40%, such as the roof collapsed, slipped, deformation, obstruction and so on. So the monitor and early warning of roof is particularly important. State of motion is closely related to mine roof pressure. Roof support pressure or resistance can be measured by the pressure sensor. The data send to the ring Ethernet underground and transmit to the monitoring center of ground. Through information analysis processing, it could provide real-time data and early warning, alarm information. Applied time series theory analysis and forecasting future pressure changes, can master the roof movement trends and regularity, guide safe production. So the decisions have some practical significance.

Keywords: *mine roof, pressure measuring, dynamic monitoring, safety forecast, time series*

1. Introduction

China is one of the largest coal producer and consumer countries in the world [1], [7-8]. With the recent increase in capacity, increasing the intensity of exploitation and transfer to deep mining, coal mine roof safety issues increasingly apparent.Coal-related security incidents frequently occur, and the security situation remains grim. As we know, due to the complexity of coal resources, storage conditions, and geological disaster-prone coal mines, China coal mine accidents and deaths accounted to about 80% total of the world. In the accident occurred, roof accident has accounted for around 40%,Such as the roof collapsed, slipped, deformation, obstruction and so on. So the roof monitoring and early warning is particularly important.

State of motion is closely related to mine roof pressure. Roof support pressure can be measured by the strain gauges sensor locating on bracket. The motion of the roof is non-linear.

2. Fully Mechanized Working Face Roof Pressure Monitoring System

The above monitoring system has following main features and technical parameters:
(1) System Monitoring Points: 1-64 monitoring station (up to 192 points);
(2) Measurement range: 0 - 60 MPA;
(3) Comprehensive error <2.5%;
(4) Display output: LCD, 20 × 4 (LED backlight)
(5) Bus interface: RS-485 or CAN Bus;
(6) Enterprise standard communication protocol short frames;
(7) Communication fault check (CRC);
(8) Communication rate: 2400bps;
(9) Supply voltage: 18V, intrinsically safe power supply;
(10) Ambient temperature: 0 - 40□; Relative Humidity: 0 - 95% RH;
(11) Form of intrinsic safety explosion-proof: Exib1.

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3. The Working Principle of Remote Monitoring System

There are four parts in the monitoring system: (1) Down hole monitoring equipment layer; (2) data collection and monitoring layer; (3) application server layer; (4) the remote client. Figure 1 is the long-range communications system to monitor schematic.

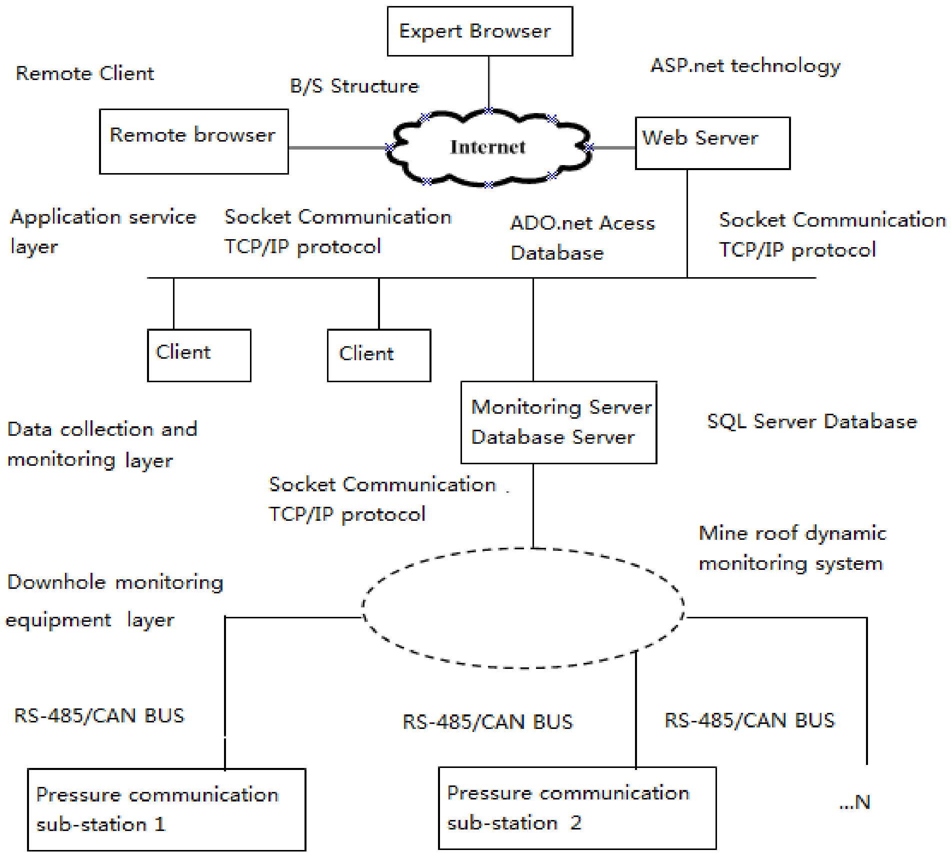

Figure 1. Long-range Communications Systems to Monitor Schematic

3.1. Down Hole Monitoring Equipment Layer

Collecting data from bracket sensors of working face underground, every pressure communication sub-station has RS-485 or CAN interface, it can connect with underground ring Ethernet through NPort interface.

Underground section used two isolated RS-485 Bus. Communication master station connected to the surveyed area communication sub-station. It can be connected to 16 measuring stations. Surveyed area communication sub-station take on different monitoring functions, generally a communication sub-station responsible for monitoring a mining face and roadway. Each communication sub-station can connect maximum 64 monitoring sites, extension or sensor, which can meet the domestic large-scale mines and layout pressure monitoring needs. Different types of monitoring sites used a unified coding. Through the communication protocol identifier could distinguish different types of parameters.

Communication master embedded DE311 communication interface (NPort interface).In addition to support Ethernet (TCP/IP protocol) data transmission, it also support telephone line or a single mode optical fiber data transmission. Underground communication master station via a telephone line, single-mode fiber or Ethernet ring network could connect with ground monitoring server connection.

3.2. Data Collection and Monitoring Layer

The layer can receive data that came from the underground ring Ethernet real-time, stored in the monitor server/database server. Through information analysis processing, it could provide real-time data and early warning, alarm information. The database could update and maintenance in time; it also responsible for sending real-time data to the web server. For different hardware architectures and operating systems on a network of computers, TCP/IP network protocol has the ability to communicate each other, so the layer and the underground field control layer communications using TCP/IP protocol.

3.3. The Application Server Layer

This layer can be used to manage web pages, and make these pages through a local network or the Internet for customer browser. Real-time data of web server get information from the data collection and monitoring layer monitoring server and available. Web server could access monitoring server database using ADO.NET technology.

3.4. The Remote Client

Accept client browser requests, via the Internet access data of application service layer [1].

4. Time Series Basic Algorithm

Time series has the ability to express nonlinear characteristics [2]. Applied time series theory analysis and forecasting future pressure changes, can master the roof movement trends and regularity, could guide safe production. So the decisions have some practical significance [3-4].Time series models have four basic forms:

(1) AR model: autoregressive model;
(2) (2)MA model: moving-average;
(3) ARMA model: Auto-regressive Moving-Average；
(4) (4)ARIMA model: Autoregressive Integrated Moving Average Model；

Next, let's take ARIMA model for an example, to be discussed. Assuming a random process with d of unit root, after it passes through d times the differential can be transformed into a stationary autoregressive moving average process. The stochastic process is called single whole autoregressive moving average process [2].

Consider the following model:

$$\Phi(L)\ \Delta^d y_t = \Theta(L)u_t \tag{1}$$

$\Phi(L)$, which is a stationary autoregressive operator. The root of $\Phi(L) = 0$ is greater than 1. $\Theta(L)$, it represents reversible moving average operator. If we take:

$$x_t = \Delta^d y_t \tag{2}$$

Equation (1) can be expressed as:

$$\Phi(L)x_t = \Theta(L)u_t \tag{3}$$

It means that y_t after a d time difference, it could be represented by a stable, reversible $ARMA$ process x_t.

After d time difference, random process y_t can be transformed into a smooth, reversible stochastic process. $\Phi(L)$, is a p-order autoregressive operator, $\Theta(L)$, is the moving average operator of q-order. y_t, is also called (p, d, q)-order single whole autoregressive moving average model, denoted by $ARIMA(p, d, q)$. ARIMA process is also called autoregressive integrated moving average process. $\Phi(L)$、Δd, call the generalized autoregressive operator.

When p ≠ 0, d = 0, q ≠ 0, $ARIMA(p, d, q)$ becomes the process $ARIMA(p, q)$;
When d = 0, p = 0, q ≠ 0, $ARIMA(p, d, q)$ becomes the process $MA(q)$;
When d = q = 0, $ARIMA(p, d, q)$ becomes the process $AR(p)$;
And when p = d = q = 0, the $ARIMA(p, d, q)$ processing becomes white noise process;

5. Roof Integrated System Dynamic Monitoring Time Series Modeling Methods and Procedures

The basic idea of the ARIMA model is to predict the changing of roof pressure as the data sequence formed by a random sequence, using a mathematical model to describe the approximate sequence. This model is used to approximate description of this sequence. Once the model is identified, the time series can use the past values and the present value to predict future values. Next, let us illustrates the time series modeling and forecasting procedures. This method consists of the following five steps:

(1) Data Inspection

For fully mechanized coal mining face working resistance of support, it first should inspect real-time data for data validation, testing time series sample stability, normality, periodic, zero-mean, make the necessary data processing. If the time series normality or smooth is not enough well, it need for data conversion. Often there are two methods: a difference transformation (using the transform-Create Time Series) and logarithmic transformations proceed (using the Transform-Compute). Generally it should be repeating transform, compare, until the data sequence normality, stability, to achieve a relatively optimal.

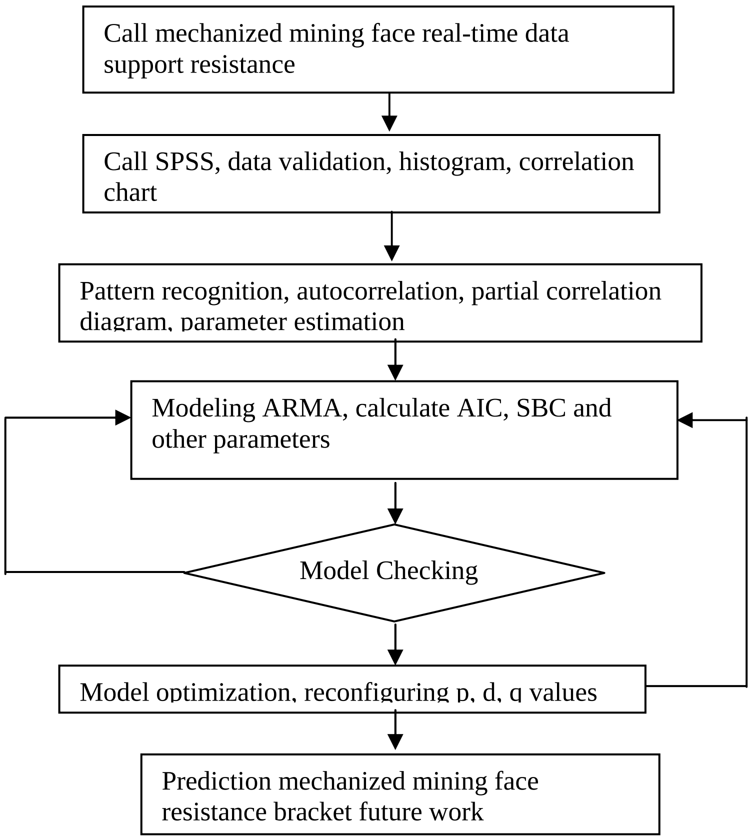

Figure 2. Time Series Modeling Steps

(2) Pattern Recognition

Using autocorrelation analysis and partial correlation analysis, discriminate model form and order, by analyzing the time series sample, comparing them individually and calculating AIC values (or SBC value), when AIC is the minimum value , the model is determined. Then determine the type form of the model, to determine p, d, q of order.

(3) Parameters estimation

Using maximum likelihood estimation or least squares estimation method to estimate φ, θ parameter values and significance tests performed.

(4) Model testing

Test new model is whether reasonable or not. If the test is not passed, then adjust (p, q) values, re-estimate parameters and test repeated until get acceptance date. However, above three processes of model identification, parameter estimation, testing correction can influence each other, sometimes need cross, repeated experiments, in order to ultimately determine the model form.

(5) Model prediction

Prediction roof moving state at some time in the future, based on predictive model to calculate the predicted value [5-6].

6. Roof Time Series Prediction Engineering Practice

Figure 3 is # 2 stents average working resistance raw data map, from fully mechanized coal face in a mine in Inner Mongolia, China. A total of 44 of the data set, the data collected once every five minutes. For the convenience of data processing, the paper select each data collection time interval of 1 hour, unit is MPA. First, the raw data applied SPSS14 software for autocorrelation and partial correlation analysis. Get Figure 4 and Figure 5. Seen from the Figure 4 and 5, the sample sequence data from the correlation coefficient oscillates around a fixed horizontal, and at periodic gradually decreases, so it can know that the time series is substantially stationary. So it can be use time series to predict the future data.

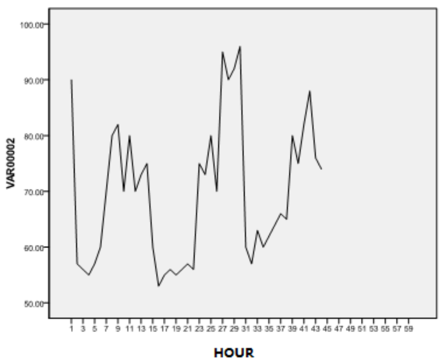

Figure 3. Average Working Resistance Raw Data Figure

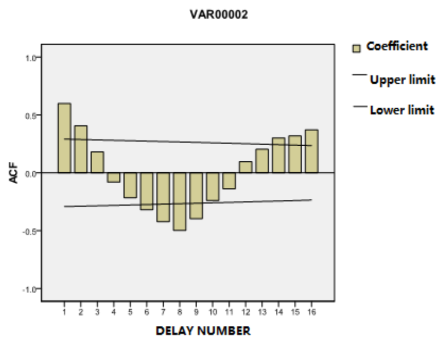

Figure 4. Autocorrelation

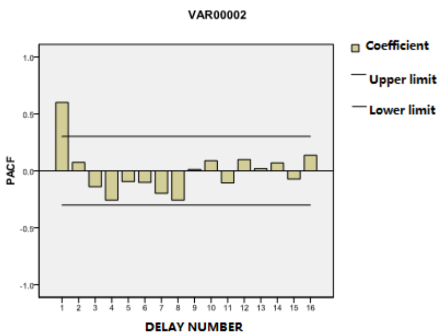

Figure 5. Partial Correlation Diagram

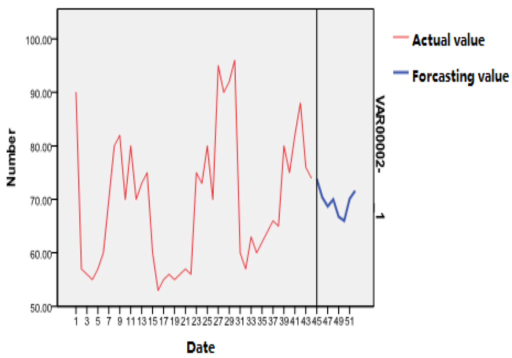

Figure 6. Forecast Results

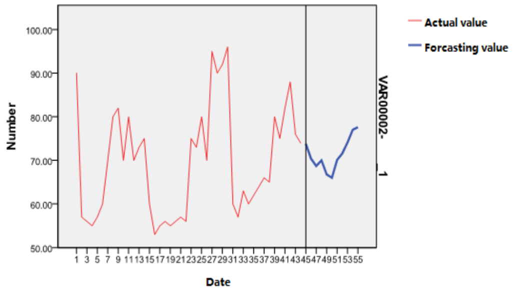

Figure 7. Forecast Results

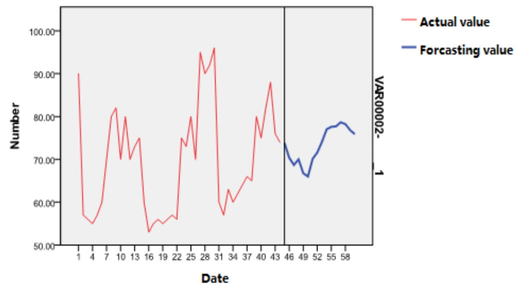

Figure 8. Forecast Results

From SPSS table can be found in the autocorrelation coefficients and partial correlation coefficients. According to Coefficient determined the model parameter values. Here, take p = 8, q = 1, using ARIMA (8,0,1) model. Figure 6, 7, 8 shows the predicted results.
Figure 6 forecast the date from 45 hours to 51 hours, Predicting data and actual values match, goodness of fit is better.

Figure 7 predicts value after 55 hour, goodness of fit is better still good.

Figure 8 is forecast value after 59 hour, the precision of prediction reduced.

Seen to be over time, it must allow the system to re-learn, its accuracy will improve. Table 1 gives the comparison between predicting value and the actual value.

Table 1. Forecast Results

No.	Actual values	predicting value	|difference|	error percentage
45	72.81	73.81	2.43	3.3375
46	70.47	70.38	1.77	2.5117
47	69.24	68.7	0.76	1.098
48	71.45	70	4.69	6.564
49	68.32	66.76	2.31	3.3811
50	65.31	66.01	4.79	7.334
51	72.47	70.1	0.86	1.1867
52	73.84	71.61	0.27	0.366
53	76.01	74.11	1.01	1.329
54	76.19	77.02	1.41	1.851
55	81.2	77.6	3.48	4.2857
56	82.4	77.72	3.74	4.5388
57	84.7	78.66	6.48	7.6505
58	85.6	78.22	8.76	10.2336
59	79.3	76.84	2.46	3.1021

7. Conclusion

The application of integrated system of C/S+B/S of the network topology enhance the speed comunication of mine networks,as well as improve the entire control network communications reliability. The data send to the ring Ethernet underground and transmit to the monitoring center of ground. Through information analysis processing, it could provide real-time data and early warning, alarm information.Using time series methods, we can better predict mine coal roof resistance, master the roof moving and changing law. To strengthening of roof support and maintenance, reduce security incidents, guiding for safe production of coalmine enterprise, has important practical significance.

Acknowledgements

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