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Research on Rock Burst Monitoring and Early Warning Technology Based on RBF Neural Network

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Abstract

China is one of the most serious coal mine accidents in the countries of the world. All of the accidents, rock burst is one of them. The rock burst in coal and rock mass, refers to the sudden power failure, release a large number of catastrophic dynamic phenomena of energy. It can be destroy the roadway roof, cause other mine disasters, casualties and so on. In China, the mine number with rock burst dangerous accounted for more than 20% of the total, Shandong Qufu Xing cun coal mine among them. In order to prevent to the happen of accident, the coal mine enterprise had been install all kinds of monitoring system, such as SOS micro seismic system , Fully mechanized working face resistance of support system and so on. Using sensors measuring and computer technology, the data had been getting from the underground 1000 meters. According to the internal link of pressure behavior between the basic regularity and variable, RBF neural network had been set up. From the model, it can forecast the risk index of rock burst, reveal the superincumbent stratum roof movement; master the process of state and changes in the laws of underground pressure. It is important significance to guide safe production of coal mine enterprises.

Keywords: *rock burst, monitoring and forecasting, RBF neural network, working face, roof pressure, micro seismic*

1. Introduction

With the development of China, the demand for coal mine is more and more. And coal-related security incidents frequently occur, and the security situation remains grim. All of various types of coal mine accidents in production; the roof rock accident is one of them. Rock burst is a sudden power failure of coal and rock mass, the release of large amounts of energy catastrophic dynamic phenomena, it can be destroy the roadway roof, cause other mine disasters, casualties and significant loss of life and property [1].

In recent years, with the increase of mining depth, geological conditions are complex, constantly improve the comprehensive mechanical coal mining degree, rock burst pressure appears more and more prominent. According to the intensity, rock burst is usually divided into three classes: mild shock, medium impact, and strong impact of three levels. When it occurs, may induce the magnitude 3~4 earthquakes, the maximum can reach level 5~6. According to the impact orientation identification results, Xing cun coal rock belongs to the third class, the strong impact tendency.

There are many factors affect the birth of rock burst, such as natural factors, technical factors, management factors. Natural factors include the original rock stress, tectonic stress, coal seam conditions; technical factors including the local stress concentration, mining speed, beyond the coal seam mining, prevention measures are inadequate; management factors include inadequate investment, the unreasonable operation procedures, responsibility heart is not strong, staff training is not in place.

Because of the hazards of rock burst is huge, prediction of impact pressure, has attracted wide attention all over the world. There are many prediction methods, such as: comprehensive index method, the drilling method, seismic method, sound, electromagnetic radiation method, test method and so on. Many domestic coal enterprises in china have been set up many independent monitoring and forecasting system, these products purchase from

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different countries and companies. Using sensor measuring and computer technology, the data had been getting from the underground more than 1000 meters. The monitoring system including SOS micro seismic system, fully mechanized working face resistance of support system and so on. But these products with different detection principles, the detected information is incomplete, imprecise, incomplete and sometimes contradictory. The parameters are non-linear. According to the internal link of pressure behavior between the basic regularity and variable, using RBF neural network technology to be the information fusion. From the data information, it can reveal the superincumbent stratum roof movement; master the process of state and changes in the laws of underground pressure. There is important significance to guide safe production of coal mine enterprises.

2. Rock Burst Monitoring Principle

2.1. Micro Seismic System

The new generation SOS micro seismic monitoring instrument purchased from Portland. It was design and manufacture by Polish Mining Research Institute of Mining Institute of Seismology. The main purpose of micro seismic is predicting rock burst [2].

The SOS micro seismic monitoring system can be achieved, including the rock burst on mine earthquake signals over long distances no more than 10km in real time, dynamically and automatically monitoring, getting full vibration waveform of the rock burst and mine earthquake signal. Software can accurately calculate the energy greater than 102J of the coal-rock shock occurred at a time, include energy and three-dimensional space coordinates, to determine each mine earthquake shock type, to determine the vibration of the power source rock mine pressure level of risk assessment and forecast. And through the application of the SOS micro seismic monitoring system, engineer can analyze the mine overburden fracture, describe the migration of the space rock structure motion and stress field evolution for coal mine safety production.

The system is mainly composed of underground and ground mounted three parts: 16 DLM-2001 detection probes, floor mounted 16 channel DLM-SO signal acquisition station, and AS-1 signal recorder and so on, they complement each other to form a complete system of work.

Through the relevant software, the system can accurately calculate the 3D coordinates of time, energy and space of coal and rock mass energy greater than 10^2J shock occurs, determine the motion type for each mine earthquake, judge the vibration generating source, carries on the appraisal to the mine rock burst hazard degree, can greatly reduce the loss of pressure disaster impact coal mine, getting enormous economic benefits and social benefits. Through the application of SOS micro seismic monitoring system, it can analysis of the mine overburden rock fracture information, accurate describe spatial strata structure movement and stress field evolution law, serves for the safety in production of coal mine. The research and field application results of implementation will bring a beneficial reference for rock burst and other dynamic disaster prevention and other aspects, and achieve huge economic and social benefits.

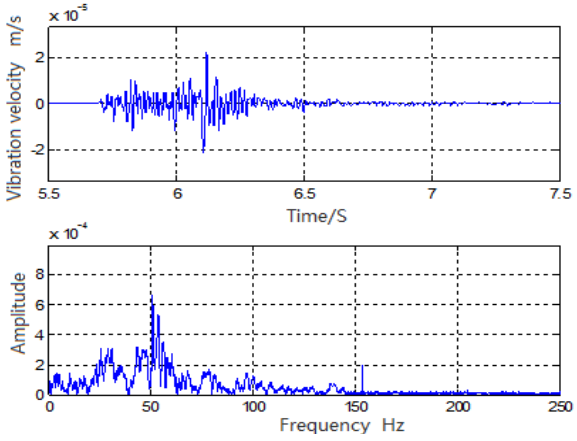

Figure 1. Strong Mining Earthquake Wave and Parameter Changes

In general, vibration of elastic energy release process is more big, the vibration wave propagation speed, amplitude is bigger; affected by geological structure and stratum lithology complex geological environmental factors, there are vibration wave propagation deviation between in coal and rock and the ideal state. Moreover, the vibration frequency is low, focused on the following 20Hz, vibration frequency range under special circumstances may be slightly larger, but in the process of vibration energy attenuation, frequency range of motion increased to a certain degree. Most vibration propagation time between 1 ~ 2.5 second, the same elastic energy release in a shorter time, the extent of damage to the coal and rock mass is larger. In the vibration energy attenuation stage, energy is relatively weak, the vibration speed slow down, reduce amplitude, main frequency also increased.

In wave propagation, wave velocity is greater, indicates that the wave from the center of the greater, the amplitude, the corresponding kinetic energy is greater. When strong rock burst energy level more than 10^5J occurs, the vibration wave velocity increases sharply, the amplitude of vibration is increased to a large amplitude, energy release in a short period of time.

2.2. Fully Mechanized Working Face Resistance of Support

The basic means of roof supporting in working faces is the hydraulic support or single hydraulic prop, emulsion as the pressure transfer medium, ability to support the roof rack or pillars known as the support resistance, support resistance reflects the roof on intensity of support equipment, pressure can be revealed through the medium of roof pressure support or pillar cavity. Measurement of hydraulic pressure measurement way have many methods, this system adopts the resistance strain measuring method [2].

The resistance is connected with shield powered support. Using strain gauge pressure sensors or vibrating wire pressure sensor. The emulsion of the pillars of the internal pressure is delivered to the sensor, the sensor output of the analog signal converted by the circuit after the computer acquisition. The total collection real-time pressure information includes three parts: the anterior column pressure, posterior column pressure and the probe beam pressure.

The resistance strain sensor has the advantages of simple structure, small volume, high response frequency, easy to design the structure. It is widely applied in the measurement of pressure field. The basic principle of resistance strain sensor is a strain gauge, consisting of a bridge, when the bridge arm resistance change, bridge loses balance; the bridge output an unbalanced voltage. The output voltage and the size of the bridge arm changes proportional relationship. The weak output voltage signal through the amplifier output to A/D circuit switched by the computer acquisition and processing [4-5].

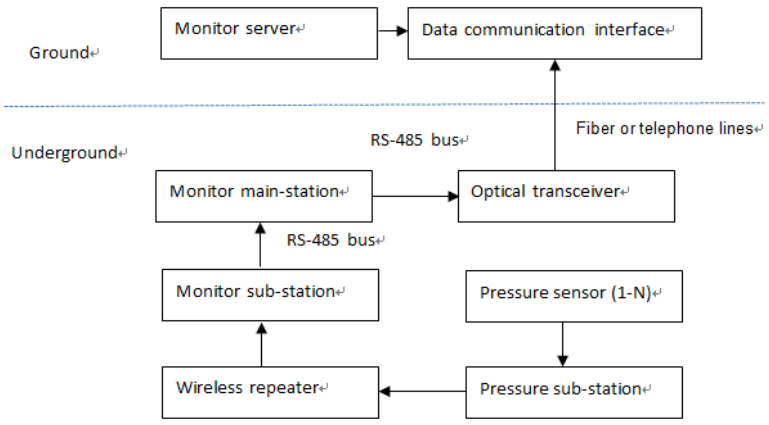

Figure 2. The Principle of Wireless Pressure Monitoring

Step and strength of the working face support resistance monitoring role mainly in: master the law of cycle pressure and strata behavior; analyze and verify the adaptability of the supports on the roof conditions; adjust supports reasonable control top state; roof accident prediction that may occur; bracket failure rate of the hydraulic system monitoring, and easy to correctly guide the production.

Ground monitoring server and down hole data transmission support multiple transmission modes: Industrial Ethernet bus transmission mode; RDS telephone line mode; single-mode fiber transmission mode. RDS communication technology using baseband type isolation transmission mode and balanced type floating communication technology; In the telephone communication in high noise environment with stable transmission, cable 20km, does not require special cable laying, may constitute the most economic monitoring system.

Ground parts include the monitoring server, communication interface and so on. Underground equipment, including fully mechanized support wireless pressure monitoring station; intrinsically safe wireless monitoring station; intrinsically safe monitoring station; intrinsically safe data transceiver; wireless repeater; junction box and supporting explosion-proof power supply, cable composition. Dynamic monitoring system coal mine adopts multilevel distributed structure, intrinsic safety design.

Communication master station and multi station communication substation the master-slave relationship, between the master station and the substation is connected by a bus. Communication station fixed set address coding, master followed by patrol each substation, substation receives the survey instructions, the station has been stored data frame, is can be transmitted to the communication station. Communication master station sent each data to the ground receiving host.

In recent years, wireless network technology has been widely used in coal mine. Mine pressure monitoring system of wireless network to abandon the cable way, to realize the fast network in the field installation and replacement battery. The communication speed has improve greatly, reduces the communication time response. Wireless transmission reliability get guarantee effectively. In the effective communication range, the concentrator can accord various algorithm acquire to optimal transmission route.

The whole system adopts OLDM wireless network technology, wireless network communication. The wireless pressure monitoring station detects data information, and then transmits the data to the concentrator according to routing protocol. Among the wireless pressure monitoring station can communicate freely. When a wireless pressure monitoring station failure, other nodes can self-organize network, choose another transmission link, improve the reliability of network communication. Sensors get the pressure data through the 433MHz wireless transmission, transmitted to the communication station. And then through the communication substation cable upload to the ground server.

3. The Monitoring Parameter

E3207 working face locate on Qufu Xing Cun coal mine, Shandong province, elevation of E3207 working face is from -1200m to -1300m, fault development, dip angle of coal seam is 0 ~ 30 °, an average of 18 °; coal seam thickness is 2.5 ~ 7.5m, average 7.15m; to a length of about 840m, the tendency length is about 115m. The data collected from SOS micro seismic system, fully mechanized working face resistance of support system. Fully mechanized working face resistance of support system monitoring parameter is pressure (unit is KN).There are seven pressure sensors, every 5 minutes a data acquisition. In order to process the data of convenience, an average of seven daily value of sensor were applied. SOS micro seismic system monitoring parameters are vibration energy (unit is J) and vibration number. Every day, the mining speed (unit is m) is recorded. As we know, the rock burst is also in contact with the advance speed.

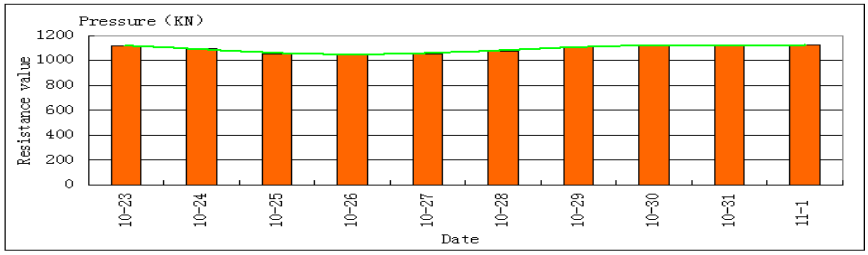

Figure 3. The Data of Resistance of Support System

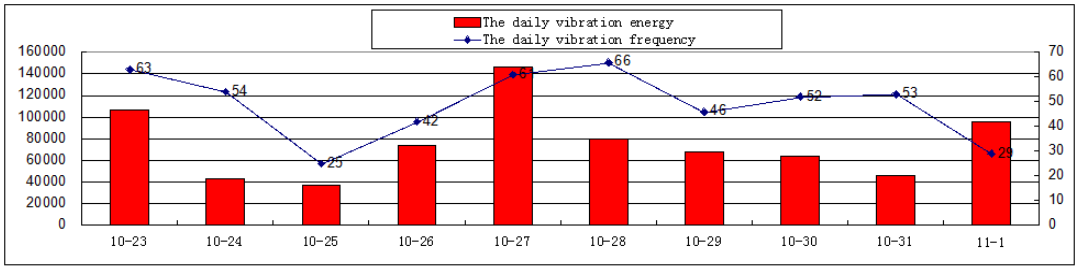

Figure 4. The Data of Micro Seismic

4. RBF Neural Networks

In the prediction process of rock burst, a large amount of data had been obtained, these data is random and nonlinear, and was closely related with the time. At the same time, the data also has the correlation between each other. The RBF neural network has strongly applicable to complex environments and multi object control requirement, and has the characteristic of approaching any nonlinear continuous function with arbitrary precision, and thus very suitable for rock burst prediction research [3].

As we know, a radial basis function (RBF) neural network has an input layer, a hidden layer and an output layer. The neurons in the hidden layer contain Gaussian transfer functions whose outputs are inversely proportional to the distance from the center of the neuron.

RBF neural network is the radial basis function (Radial Basis Function) neural network, usually consists of an input layer, one hidden layer and one output layer. The hidden layer is a group of radial basis function, and each implicit parameter vector layer node related center and width. Radial basis function has a variety of forms, the general Gauss function. RBF neural network is a feed forward network of a good performance. It has the best approximation performance, with output weight linear relationship in the structure, training method is fast and easy, no local optimum problem.The activation function of radial basis function neural network is in between the input vector and the weight vector distance $\|dist\|$ as variable. The general expression for the activation function [6-7]:

$$R(\|dist\|) = e^{-\|dist\|^2} \quad (1)$$

With the decrease of distance between the weights and the input vector, the output of the network is increasing.

For RBF neural network learning algorithm, there are three parameters need to solve: the center of basic function, variance and the weights from hidden layer to the output layer. Among them, the radial basis function used is the Gauss function. Therefore the activation function of radial basis function neural network can be expressed as:

$$R(x_p - c_i) = \exp\left[-\frac{1}{2\sigma^2}\|x_p - c_i\|^2\right] \quad (2)$$

In the formula:

$\|x_p - x_c\|$ is Euclidean norm;

c is Gauss function center;

σ is the variance of Gauss function.

From the structure of radial basis function neural network, it can get the network output:

$$y_j = \sum_{i=1}^{h} w_{ij} \exp\left[-\frac{1}{2\sigma^2}\|x_p - c_i\|^2\right], j = 1,2,\ldots n \quad (3)$$

In the formula: $x_p = (x_1^p, x_2^p, \cdots, x_m^p)^T$ is the P input samples;

$p = 1,2, \cdots, P$, P is the total number of samples;

c_i represent the network nodes of the hidden layer centers;

w_{ij} is the hidden layer to the output layer weights;

$i = 1,2, \cdots, h$ is the number of hidden layer nodes.

y_i is the actual output the output node and the input samples corresponding to the network.

Let d is the desired output values of samples, then the variance based function can be expressed as:

$$\sigma = \frac{1}{p} \sum_{j}^{m} \left\| d_j - y_j c_i \right\|^2 \quad (4)$$

5. RBF Model

According above theory, A RBF model had been set up. This model has four input parameters.

(1) Pressure, get from fully mechanized working face resistance of support system.

(2) Speed of coal mining.

(3) The daily vibration energy.

(4) The daily vibration frequency.

The model has only one output parameter; it is the risk index of rock burst. The risk index of rock burst divided into four grades. Each assignment is 1, 2, 3, and 4.

(1) No risk, no mine shock or vibration energy between 10^2~10^3J, no underground pressure behavior.

(2) Weak risk, vibration energy between 10^2~10^{5J}, no underground pressure behavior.

(3) Medium risk, vibration energy between 102~$106^{J,}$ with the presentation of the mine pressure, deformation, but does not affect the production

(4) High risk, vibration energy between , Mine pressure appear obvious 10^2~10^8J.

RBF model predictions can be used in a variety of methods, such as VC++ programming, matlab2012 toolbox and so on. Now, we use spss17 statistics software to realize it. The software has RBF toolbox. Among ten days data, nine days as training data, one day as predicted data. Table 1 is the origin data and RBF predicted results. From the predicted results we can know the Exper_value and RBF_predicted value is colse to, and fits in with the actual situation of working field, results indicate that the proposed model is appropriate. Figure 5 is The RBF model based on SPSS [8]. The hidden layer activation function is Softmax. The output layer activation function is identity. Figure 6 is the residuals of RBF residuals; residuals error is within acceptable limits.

Table 1. The Origin Data and RBF Predicted Results

Pressure（KN）	Energy（J）	Frequency	Speed (m)	Expert_value	RBF_ predicted value
1117.00	106435.00	53.00	3.00	2.00	2.00
1092.00	43133.00	49.00	3.00	1.00	1.04
1051.00	36816.00	19.00	0.60	1.00	1.00
1055.00	73593.00	32.00	3.00	2.00	2.00
1056.00	146179.00	48.00	3.00	3.00	3.00
1076.00	80174.00	51.00	3.30	2.00	2.00
1108.00	68017.00	35.00	3.00	2.00	2.03
1118.00	63981.00	43.00	3.00	2.00	1.97
1116.00	46418.00	46.00	3.30	1.00	1.00
1123.00	95983.00	23.00	2.40	2.00	2.00

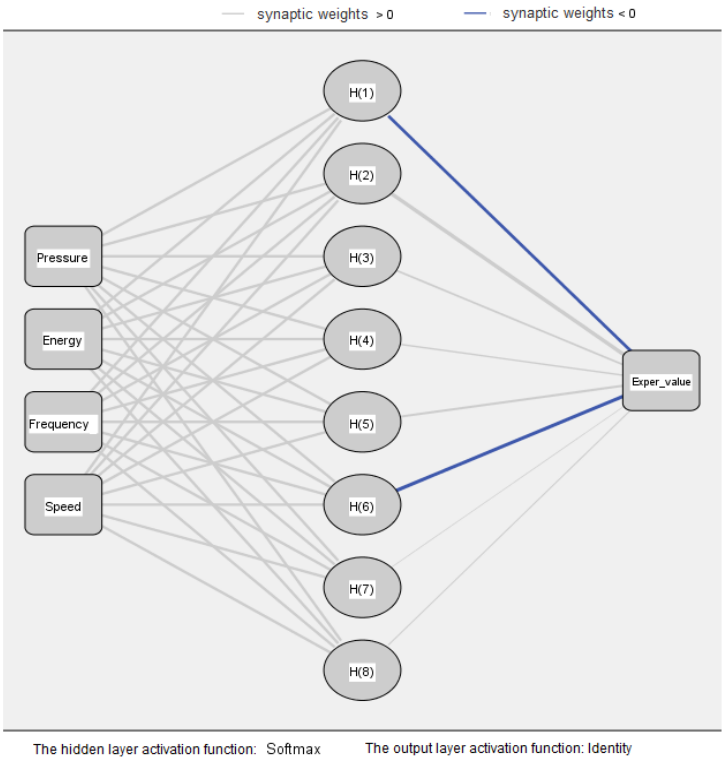

Figure 5. The RBF Model Based on SPSS

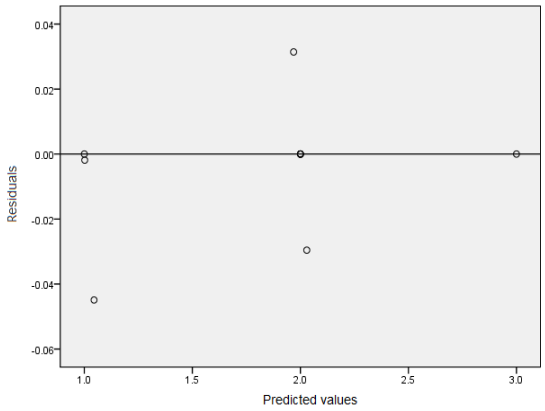

Figure 6. The Residuals of RBF

6. Conclusion

The impact of early warning indicators of mine micro seismic pressure is: 1) Vibration energy is less than 1×10^4 J region, no danger. The vibration energy is higher than 1×10^4 J, less than 1×10^5 J region, dangerous rock burst disaster, is a weak shock hazard area. And vibration energy is large, dangerous rock burst disaster is bigger; 2) The strong strata behavior occurred before, mine earthquakes and seismic energy increases rapidly, maintained at a high level, until the occurrence of strong mining large pressure, mine earthquakes and seismic energy reduces the micro seismic signal; 3) Frequency firstly increases gradually, and then began to decline sharply, when micro seismic signal frequency increased again, suggesting that there may burst.

Using RBF neural network technology, different information can be fusion. From the data information, it can reveal the superincumbent stratum roof movement; master the process of state and changes in the laws of underground pressure. There is important significance to guide safe production of coal mine enterprises.

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