Research on Intelligent Diagnosis of Fault Data of Large and Medium-Sized Pumping Stations Under Information Evaluation System

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Abstract. In order to improve the fault detection capability of large and medium-sized pump stations, the abnormal feature diagnosis of the fault data is required, and the intelligent diagnosis algorithm of the fault data of the large and medium-sized pump station under the information-based evaluation system is put forward. The fault data sensing information acquisition node distribution model of the large and medium-sized pump station is constructed, the multi-sensor fusion sampling method is adopted to sample the fault data of the large and medium-sized pump station, and the statistical feature quantity of the fault data of the large and medium-sized pump station is extracted. The fault data set of large and medium-sized pump station is used to detect and optimize the abnormal working condition of the fault data set of the large and medium-sized pump station, and the fault diagnosis of the large and medium-sized pump station is realized according to the detection result. The simulation results show that the accuracy of the fault data set of large and medium pump station is high, and the real-time and self-adaptability of the fault detection are better.

Keywords: Information-based evaluation system · Large and medium-sized pump station · Fault data · Intelligent diagnosis

1 Introduction

The equipment structure of large and medium-sized pump station is complicated and the working environment is bad. The large and medium-sized pump station equipment includes power supply system fault, cooling system fault and generator fault. We need to accurately detect and identify the faults of the large and medium-sized pump station [1]. This paper constructs a big data analysis model to detect the faults of large and medium-sized pump stations. To improve the ability of accurate detection and fault diagnosis of large and medium-sized pump stations, it is necessary to combine big data fusion and statistical analysis. The fault diagnosis model of large and medium-sized pump stations is constructed by using the characteristic information of abnormal working conditions of large and medium-sized pump stations and the fault data set of monitoring abnormal working conditions. To improve its fault detection capability is of great significance to improve the fault analysis and real-time diagnosis capability of

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equipment in large and medium-sized pump stations. The research on fault data sets of large and medium-sized pumping stations has attracted much attention [2].

Fault diagnosis of large and medium-sized pumping station equipment is a huge system engineering, which covers signal analysis, data processing and artificial intelligence diagnosis. In the traditional methods, the detection methods of fault data set of large and medium-sized pumping stations mainly include fuzzy detection method, wavelet detection method and statistical analysis method, and the feature analysis model of fault data set of large and medium-sized pumping station is established [3]. Combined with expert system identification method, the fault data set of large and medium-sized pumping stations is detected by fuzzy detection method, wavelet detection method and statistical analysis method [4]. The fault data set of large and medium-sized pumping stations is collected to improve the fault analysis ability of large and medium-sized pumping stations, but the adaptability of traditional methods for fault diagnosis of large and medium-sized pumping stations is not good and the ability of intelligent diagnosis is not strong [5].

In order to solve the above problems, an intelligent diagnosis algorithm for fault data of large and medium-sized pumping stations based on information evaluation system is proposed in this paper. The distribution model of fault data sensing information acquisition node for large and medium-sized pumping stations is constructed. Firstly, the multi-sensor fusion sampling method is used to sample the fault data of large and medium-sized pumping stations, and the statistical characteristics of fault data of large and medium-sized pumping stations are extracted. The sample information analysis and regression detection of fault data of large and medium-sized pumping stations are carried out by using the method of abnormal map feature extraction. Then the abnormal working condition characteristics of fault data. This paper analyzes the difference distribution characteristics of abnormal working conditions of fault data sets of large and medium-sized pumping stations. And realizes the detection and optimization of abnormal working conditions of fault data sets of large and medium-sized pumping stations by excavating the attribute characteristics of abnormal working conditions of fault data sets and medium-sized pumping stations. According to the above contents, the simulation test is carried out and the simulation results are analyzed. The effective conclusion is drawn from the simulation results.

2 Fault Big Data Sensing Information Collection and Feature Decomposition

2.1 Information Acquisition of Abnormal Working Condition of Medium-Sized Pump Station Fault Data Set

In order to diagnose that abnormal characteristic of the fault data set of the large and medium-sized pump station, a large-data information sensing method is adopted to sample the original sample information of the fault data set of the large and medium-sized pump station. The method comprises the following steps of: carrying out multi-component characteristic reconstruction and information fitting on the collected abnormal working condition characteristic sample data of a large and medium-sized pump station fault data set [6]. And adopting a vibration sensor to carry out fault sample information acquisition of the large and medium-sized pump station equipment, combining the large data sensing information sensing method to sample the original sample information of the fault data set abnormal working condition of the large and medium-sized pump station, and carrying out fuzzy clustering on the collected abnormal working condition characteristics of the fault data set of the large and medium-sized pump station. Establish a large database of the fault data set distribution of the large and medium-sized pump station, by adopting the method of function identification and expert system identification. The fault data analysis of the large and medium-sized pump station is carried out, a fuzzy inference machine for fault diagnosis of the large and medium-sized pump station is constructed [7]. A man-machine interface and a knowledge base are combined, and the fault diagnosis of the large and medium-sized pump station is the fault diagnosis model of large and medium pump station is shown in Fig. 1.

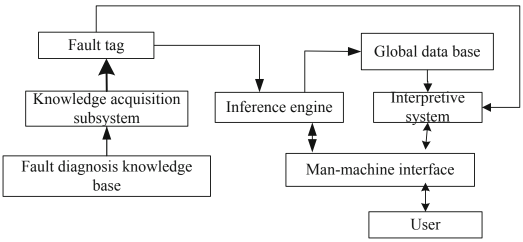

Fig. 1. The principle of intelligent fault diagnosis for large and medium-sized pump station equipment

Based on the information fusion method, a large data mining model for dynamic fault diagnosis of the large and medium-sized pump station equipment is established, by using the fuzzy information fusion scheduling method. The statistical analysis sample model of the large and medium pump station equipment under the fault condition is obtained as follows:

$$x_m(t) = \sum_{i=1}^{I} s_i(t)e^{j\varphi_{mi}} + n_m(t), -p+1 \le m \le p \tag{1}$$

In formula (1), i is the value of the input variable, e is the information fusion coefficient, m is the number of fault samples of the input node, and p is the number of input variables.

Because of the dynamic structure distribution characteristics of large and medium-sized pumping station equipment, the fuzzy state distribution set of fault samples of large and medium-sized pumping station equipment is calculated by using dynamic sensor fusion tracking and identification method, which is represented as a set of correlation functions.

$$C_N(r) = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=i+1}^{N} H\left(r - \left\|\boldsymbol{x}_i - \boldsymbol{x}_j\right\|\right) \tag{2}$$

In the formula (2), N input distribution set number of H dynamic coefficient calculation, the x_i and x_j, respectively the i and j the width of the output membership function of fuzzy subset center.

The relevant parameters of the large and medium-sized pump station equipment device are effectively detected, the number of time-domain sampling points of the fault characteristic sequence of the large and medium-sized pump station equipment is obtained by combining the working condition state prediction method [8]. The fuzzy correlation integral $C_m(r)$ is subjected to the exponential law, namely:

$$\lim_{r \to 0} C_m(r) \propto r^D \tag{3}$$

The estimated instantaneous frequency of the fault signal of the equipment and equipment of large and medium-sized pumping stations is expressed as follows:

$$\begin{aligned} x_{id}(t+1) = wx_{id}(t) + c_1 r_1 [r_3^{t_0 > T_0} p_{id} - x_{id}(t)] \\ + c_2 r_2 [r_4^{t_g > T_g} p_{gd} - x_{id}(t)] \end{aligned} \tag{4}$$

The fault characteristic discrimination of large and medium-sized pumping station equipment is that the time delay function is $N = n - (m - 1)\tau$, and the power sensor device is used to identify the fault of large and medium-sized pumping station equipment. The statistical sequence r_i and ambiguity k_i are obtained respectively.

$$\gamma_i = \frac{\frac{1}{w} \sum_{l=0}^{w-1} [x_i(k-l) - \mu_i]^3}{\left(\frac{1}{w} \sum_{l=0}^{w-1} [x_i(k-l) - \mu_i]^2\right)^{3/2}} \tag{5}$$

$$\kappa_i = \frac{\frac{1}{w} \sum_{l=0}^{w-1} [x_i(k-l) - \mu_i]^4}{\left(\frac{1}{w} \sum_{l=0}^{w-1} [x_i(k-l) - \mu_i]^2\right)^{2}} - 3 \tag{6}$$

In the above formula, x_i represents the outlier feature distribution point of the fault sample set of large and medium-sized pumping stations, k represents the ambiguity function of the fault sample data set under a certain kind of fault state, l represents the direction vector of the distributed signal source [9, 10].

2.2 Statistical Feature Decomposition of Fault Data of Large and Medium-Sized Pumping Stations

The distribution model of fault data sensing information acquisition node in large and medium-sized pumping stations is constructed, the statistical characteristics of fault data in large and medium-sized pumping stations are decomposed [11]. And the fuzzy degree identification method is used to schedule the fault data of large and medium-sized pumping stations:

$$C_m(r) = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=i+1}^{N} H\left(r - \left\|\boldsymbol{x}_i - \boldsymbol{x}_j\right\|\right) \tag{7}$$

Multi-sensor distributed detection technology is introduced to detect faults in large and medium-sized pump stations.

The statistical characteristics of fault data abnormal diagnosis of large and medium-sized pumping station equipment are obtained as follows:

$$x(k+1) = \boldsymbol{\Phi}(k)x(k) + \boldsymbol{J}(k)\breve{\boldsymbol{M}}(k) + \tilde{\boldsymbol{w}}(k) \tag{8}$$

The basis function of abnormal working condition of equipment fault data of large and medium-sized pumping station is as follows:

$$\begin{cases} \boldsymbol{\Phi}(k) = [\boldsymbol{A}(k) - \boldsymbol{J}(k)\breve{\boldsymbol{H}}(k)] \\ \breve{\boldsymbol{w}}(k) = \boldsymbol{\Gamma}(k)\boldsymbol{w}(k) - \boldsymbol{J}(k)\breve{\boldsymbol{V}}(k) \end{cases} \tag{9}$$

According to the above analysis, the distribution model of fault data sensing information acquisition node for large and medium-sized pumping stations is constructed, and the fault data of large and medium-sized pumping stations are sampled by multi-sensor fusion sampling method, and the statistical features of fault data of large and medium-sized pumping stations are extracted, and the fault features of large and medium-sized pumping stations are analyzed and detected according to the results of feature extraction [12].

3 Optimization of Abnormal Characteristics Diagnosis in Fault Data Set of Large and Medium-Sized Pumping Stations

3.1 Detection of Differential Distribution Characteristics of Fault Abnormal Working Conditions

In that invention, the fault data set information acquisition node distribution model of the large and medium-sized pump station is constructed, and a multi-sensor fusion sampling method is adopted to carry out fault data sampling and characteristic decomposition of the large and medium-sized pump station, In this paper, the intelligent diagnosis algorithm for the fault data of large and medium-sized pump station based on the information-based evaluation system is presented. The abnormal working condition characteristic quantity of the fault data of the large and medium-sized pump station is excavated, the difference distribution characteristic of the abnormal working condition of the fault data set of the large and medium-sized pump station is analyzed [13]. The abnormal working condition component of the fault data of the large and medium-sized pump station is decomposed by the singular value, so that the abnormal working condition component of $0 \leq m$, $n \leq P-1$. Thereby obtaining the spectral characteristic parameter of the abnormal working condition of the fault data of the large and medium-sized pump station:

$$C_1 = AC_{4S}A^H \tag{10}$$

Where in the formula, A is a multi-dimensional matrix with dimension $P \times L$. The fuzzy correlation fusion function of abnormal fault data of large and medium-sized pumping stations is obtained by phase space reconstruction method.

$$a_i = \left[1, \mathrm{e}^{j2\phi_i}, \cdots \mathrm{e}^{j2(P-1)\phi_i}\right]^T \tag{11}$$

The adaptive matched filtering method is used to detect the abnormal fault data of large and medium-sized pumping stations and analyze the spectrum. The sensor spatial distribution matrix C_3, C_4, C_5, C_6, C_7 or fault detection of large and medium-sized pumping stations is obtained to represent the surge spectrum of abnormal fault data of large and medium-sized pumping stations. The characteristic components Φ, Ω, Λ are expressed as follows:

$$\Phi = diag[e^{j2\phi_1}, e^{j2\phi_2}, \cdots e^{j2\phi_I}] \tag{12}$$

$$\Omega = diag[e^{-j2\gamma_1}, e^{-j2\gamma_2}, \cdots e^{-j2\gamma L}] \tag{13}$$

$$\Lambda = diag[e^{j2w_1}, e^{j2w_2}, \cdots e^{j2wL}] \tag{14}$$

Based on the surge spectrum of large and medium-sized pumping station equipment, the difference distribution characteristics of abnormal working conditions of fault data set of large and medium-sized pumping stations are analyzed. By excavating the attribute characteristics of abnormal working conditions of fault data sets of large and medium-sized pumping stations [14]. The intelligent expert system is established to realize the distributed detection of fault points of large and medium-sized pumping station equipment:

$$j \leq \min\left[\left[\frac{T^2}{\Delta^2}\right], n\right] + 1 \tag{15}$$

Based on the above analysis, the L eigenvalues $\lambda_1, \lambda_2, \cdots, \lambda_l$ and the eigenvector matrix $Y = [y_1, y_2, \cdots, y_l]$, are obtained to construct the sample space fusion model of abnormal fault data of large and medium-sized pumping stations. According to the results of information fusion, the difference characteristics of abnormal working conditions of fault data of large and medium-sized pumping stations are analyzed. According to the difference of abnormal working conditions of fault data of large and medium-sized pumping stations, the fault sample information is extracted and the fault detection ability of large and medium-sized pumping stations is improved [15].

3.2 Fault Anomaly Feature Diagnosis Output

According to the characteristic components of the abnormal working condition data of the fault data set of large and medium-sized pumping stations, the 3D data map is reconstructed, and the fusion of the abnormal working conditions of the fault data sets of large and medium-sized pumping stations is realized by combining the fuzzy C-means clustering method, and the spatial spectral gain of the abnormal working conditions is obtained:

$$v_i(t) = \frac{V_{DC}}{2} sign[\sin(\omega t)] \tag{16}$$

The spectrum distribution of fault data sensing information of large and medium-sized pumping stations is as follows:

$$x_k = \sum_{n=0}^{N/2-1} 2(a_n \cos\frac{2\pi kn}{N} - b_n \sin\frac{2\pi kn}{N}) \quad k = 0, 1, \ldots N-1 \tag{17}$$

Wherein, a_n represents the variable scale offset of fault data of large and medium-sized pumping stations, and the abnormal working conditions of fault data sets of large and medium-sized pumping stations are excavated. By using the method of time-frequency analysis, the spectral density characteristic distribution of abnormal working conditions of fault data sets of large and medium-sized pumping stations is described as follows:

$$x = \alpha - \theta = \tan^{-1}(\frac{n_x^2 R_{load}}{\omega L_{mx}}) \tag{18}$$

$$\alpha = \tan^{-1}\left(\frac{\pi^2}{8n_x^2 R_{load}} \frac{\omega L_{lmx} - \frac{1}{\omega C_x}}{\cos^2(x)} + \tan(x)\right) \tag{19}$$

$$\theta = \alpha - x \tag{20}$$

By using the method of amplitude response characteristic analysis, the abnormal working condition characteristic distribution set of fault data set of large and medium-sized pumping stations is constructed, and the amplitude of abnormal working condition sampling of fault data sets of large and medium-sized pumping stations is represented as:

$$z_{\max} = \max_{y=n_1}^{n_2}\left\{\max_{x=m_1}^{m_2}\{z_{xy}\} - \min_{x=m_1}^{m_2}\{z_{xy}\}\right\} \tag{21}$$

According to the analysis, the fault statistical analysis model of the large and medium-sized pump station is constructed, and the dynamic detection of the abnormal working conditions of the fault data set of the large and medium-sized pump station is carried out in combination with the method of the spatial spectrum clustering analysis. The detection method combined with dynamic spectrum feature extraction and correlation matching, and the failure data sets of large and medium-sized pump stations under abnormal conditions with statistical characteristics are as follows:

$$x(t) = \sum_{i=1}^{n} c_i + r_n \tag{22}$$

In the above formula, c_i represents the fusion quantitative set of each fault feature classification, and carries on the dynamic fusion to the empirical mode component of the fault sample, and the output is as follows:

$$\frac{\partial u(x,y;t)}{\partial t} = \frac{\partial^2 u(x,y;t)}{\partial \xi^2} + c^2 \frac{\partial^2 u(x,y;t)}{\partial \eta^2} \tag{23}$$

If the dynamic state vector of large and medium-sized pumping station equipment is initialized, and the adaptive positioning method of sensor node is used to automatically detect the abnormal working conditions of fault data set of large and medium-sized pumping station, the optimal detection model is as follows:

$$\begin{aligned}&(V(a_1,\cdots,a_m)^{(\alpha_1,\cdots,\alpha_m)})^{-1}V(b_1,\cdots,b_m)^{(\beta_1,\cdots,\beta_m)}\\&=((V(a_1,\cdots,a_m)^{-1}V(b_1,\cdots,b_m))^{(\alpha_1^{-1},\cdots,\alpha_m^{-1})^T})^{(\beta_1,\cdots,\beta_m)}\end{aligned} \tag{24}$$

Where in the formula, $V(a_1,\cdots,a_m)^{-1}V(b_1,\cdots,b_m)$ is the similarity matrix of abnormal working condition distribution of fault data set of large and medium-sized pumping stations. Combined with the analysis method of phase statistical characteristics, the ambiguity characteristics of abnormal working conditions of equipment fault data in large and medium-sized pumping stations are obtained as follows:

$$
\begin{aligned}
\dot{\sigma}(X,t) &= C\dot{E} - C\dot{P}(t) \\
&= \mathrm{C} \cdot [\dot{e}^T \ddot{e}^T \cdots e^{(n)T}]^T - C \cdot [\dot{p}(t)^T \ddot{p}(t)^T \cdots P^{(n)}(t)^T]^T \\
&= C_n[e^{(n)} - p^{(n)}(t)] + \sum_{k=1}^{n-1} C_k[e^{(k)} - p^{(k)}(t)] \\
&= C_n[x_1^{(n)} - x_{1d}^{(n)} - p^{(n)}(t)] + \sum_{k=1}^{n-1} C_k[e^{(k)} - p^{(k)}(t)] \\
&= C_n[\dot{x}_n - x_{1d}^{(n)} - p^{(n)}(t)] + \sum_{k=1}^{n-1} C_k[e^{(k)} - p^{(k)}(t)] \\
&= C_n[f(X,t) + \Delta f(X,t) + - x_{1d}^{(n)} - p(t)^{(n)}] \\
&\quad + \sum_{k=1}^{n-1} C_k[e^{(k)} - p^{(k)}(t)]
\end{aligned}
\tag{25}
$$

According to the above analysis, the high-order spectral characteristics of the abnormal working condition signal of the fault data set of large and medium-sized pumping stations are extracted.

4 Simulation Test Analysis

The effectiveness of this method for dynamic detection of abnormal data sets of large and medium-sized pumping stations is verified by simulation experiments. The experimental design was carried out using Matlab 7 simulation software. In order to ensure the experimental quality, the failure data of a large and medium-sized pump station in Wuhan was used as the data set. The number of sensing nodes, root nodes and attribute categories of fault data of large and medium-sized pumping stations are 24, 5 and 5, respectively, indicating different fault state characteristics. The number of nodes collected from fault data of large and medium-sized pumping station equipment is N = 1000, and the training set of fault data sampling for large and medium-sized pumping stations is 200. The initial sampling frequency f_1 = 1.5 Hz. Termination sampling frequency of fault characteristic sampling for large and medium-sized pumping stations is set according to the above parameters. And the fault data of large and medium-sized pumping stations are sampled, and the segmented sampling results of fault sample data are shown in Fig. 2.

According to the sampling result of the fault data set of the large and medium-sized pump station of Fig. 2. The fault data set abnormal characteristic diagnosis is carried out, and the result of the detection is shown in Fig. 3.

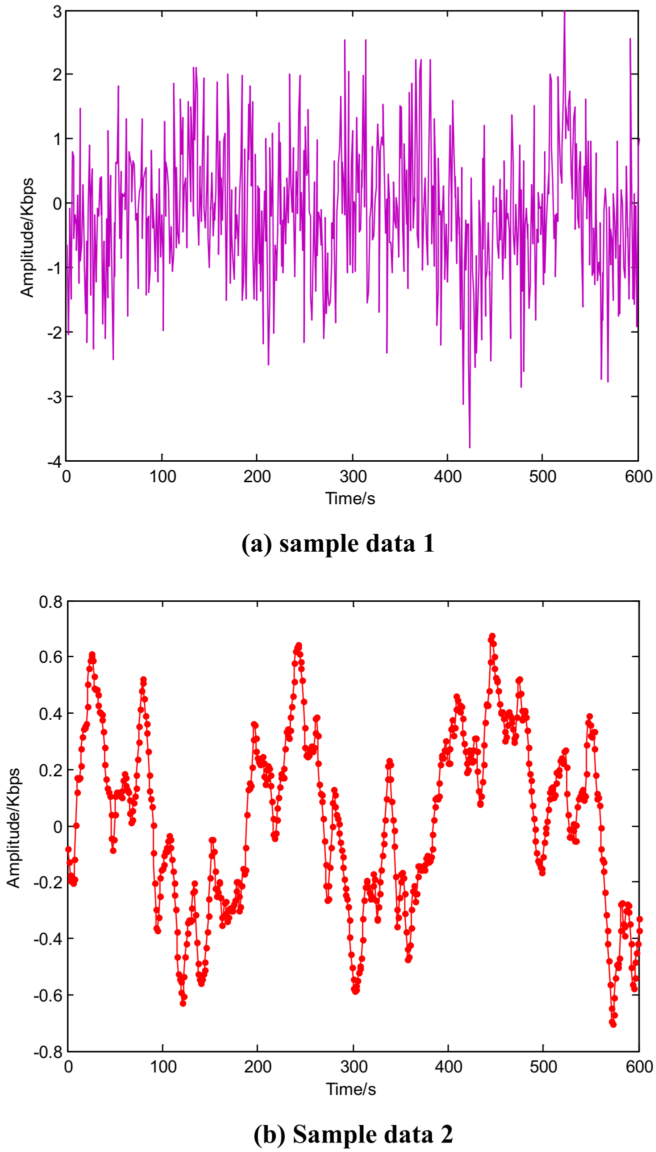

Fig. 2. Segmented sampling results of fault sample data

The accuracy of abnormal feature diagnosis of fault data set of large and medium-sized pumping stations is tested by different methods. The comparative results are shown in Table 1. The analysis Table 1 shows that the accuracy of abnormal feature

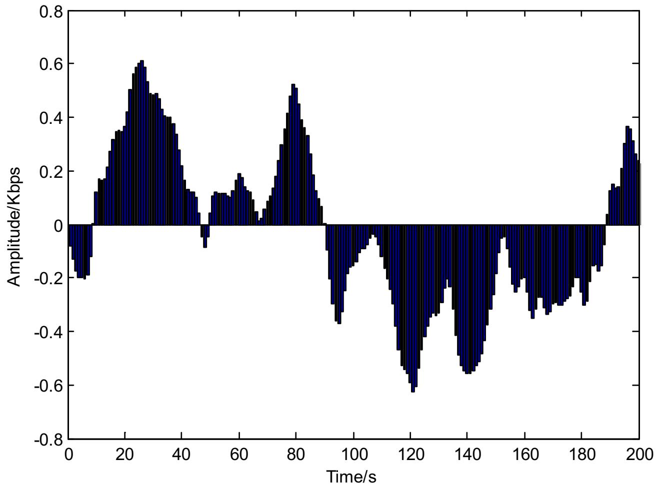

Fig. 3. Abnormal characteristic diagnosis results of Fault data of large and medium-sized pumping stations

diagnosis of fault data sets of large and medium-sized pumping stations by using this method is higher.

The experimental data in Table 1 show that the diagnostic accuracy of the proposed method is higher than that of the two traditional methods. Because the proposed method USES the multi-sensor fusion sampling method to sample the fault data of large and medium-sized pumping stations. This process makes statistical fault characteristics data more comprehensive. The proposed diagnosis accuracy is high, which is beneficial to practical application.

Table 1. Comparison of diagnostic accuracy of abnormal features in fault data sets of large and medium-sized pumping stations

Iterations	Proposed method	Reference [3]	Reference [5]
20	0.945	0.834	0.854
40	0.976	0.856	0.865
60	0.998	0.914	0.901
80	0.999	0.925	0.923

5 Conclusions

The abnormal feature diagnosis of fault data is carried out, and the intelligent diagnosis algorithm of fault data of large and medium-sized pumping stations based on information evaluation system is proposed. The distribution model of sensor information acquisition node for fault data of large and medium-sized pumping stations is constructed. The fault data of large and medium-sized pumping stations are sampled by multi-sensor fusion sampling method, the statistical characteristics of fault data of large and medium-sized pumping stations are extracted, the sample information analysis and regression detection of fault data of large and medium-sized pumping stations are carried out by using abnormal map feature extraction method, and the abnormal working condition characteristics of fault data of large and medium-sized pumping stations are excavated. This paper analyzes the difference distribution characteristics of abnormal working conditions of fault data sets of large and medium-sized pumping stations, and realizes the detection and optimization of abnormal working conditions of fault data sets of large and medium-sized pumping stations by excavating the attribute characteristics of abnormal working conditions of fault data sets of large and medium-sized pumping stations. It is found that the accuracy of abnormal feature diagnosis in fault data set of large and medium-sized pumping stations is high, the real-time and self-adaptability of fault detection is good, and the ability of fault diagnosis is improved. In order to make this study more practical, the research direction will be to improve the fault detection efficiency of large and medium-sized pumping stations in the future. To provide a favorable basis for pump station fault detection.

6 Fund Projects

Scientific Research Project of Hubei Water Resources Department in 2019; Item number: HBSLKY201909; Study on evaluation system of pumping station informatization.

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