



# Optimal Method of Load Signal Control of Power Based on State Difference Clustering

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**Abstract.** In order to improve the power grid load detection ability, an optimal method of load signal control of power based on state difference clustering is proposed, and the big data statistical analysis model of the power grid load is constructed. The clustering analysis and state mining of grid load are carried out by using the distributed detection method of association features, and the regression analysis model of grid load state difference is constructed to realize the state differential clustering of power grid load signal in high-dimensional phase space. Based on the classification and fusion of the extracted characteristic sets of grid load, big data analysis method is used to optimize the intelligent control of power grid load signal. The simulation results show that the proposed method has better accurate classification performance and lower misdivision rate, which improves the output stability of power grid load.

**Keywords:** Power grid · Load · State difference clustering · Intelligent control

## 1 Introduction

Power grid load is the infrastructure to realize terminal high voltage power supply. In carrying out power grid load supply, it is necessary to accurately forecast the power load, analyze the trend of the grid load, and realize the optimal management and dispatching of the grid load [1]. To improve the power grid load application ability, reduce the unreasonable overhead of the power load, guarantee the safe and stable operation of the power equipment infrastructure, the foundation of studying the power grid load forecast is to carry on the load classification cluster processing. According to the classification clustering analysis of power grid load, the adaptive dispatching of power load is carried out to improve the optimal management ability of power grid load. The relevant cluster analysis methods of power grid load classification are of great concern [2].

At present, expert system forecasting method and fuzzy K-means clustering method are used to classify and cluster the load of power grid, and statistical sequence analysis method is used to reconstruct and analyze the characteristic signal of power grid load. The power grid load forecasting and characteristic reorganization are realized, and the load forecasting is carried out with fuzzy clustering method. However, the intelligent control of the power grid load signal is not good and the ambiguity is large [3].

A power feedforward method combining inductance and capacitor power dynamics with load power static, dynamic feedforward feeds the energy consumed by the inductor and capacitor into the rectifier in stages, and the static feedforward feeds the output power of the PI controller to the rectifier. Stabilize the current on the grid side and reduce DC bus voltage fluctuations [4]. However, only OADs with low dimensional phase space are implemented. The compensation method based on the direct injection of the high-frequency component of the pre-inductor current can not only reduce the size of the bus filter capacitor in the power supply system, but also suppress the instability caused by the constant power load, and improve the stable operating range of the system [5]. However, the convergence of this method is poor, and the error rate of short-term power load classification is high.

In view of the above problems, the fuzzy clustering method is used to carry out the load forecasting. In this paper, an intelligent load control optimization method based on state difference clustering is proposed. The big data statistical analysis model of power grid load is constructed, and the distributed detection method of correlation features is used for the fusion clustering analysis and state mining of power grid load signal. Quantitative recursive analysis and subspace reengineering are used to analyze the structural characteristics of power grid load signal difference, and the state difference clustering of power grid load in high dimensional phase space is realized. Finally, the experimental analysis is carried out. The advantages of the proposed method in power load classification clustering and forecasting are demonstrated.

## 2 Model Construction and Pre-processing of Load Time Series in Power Grid

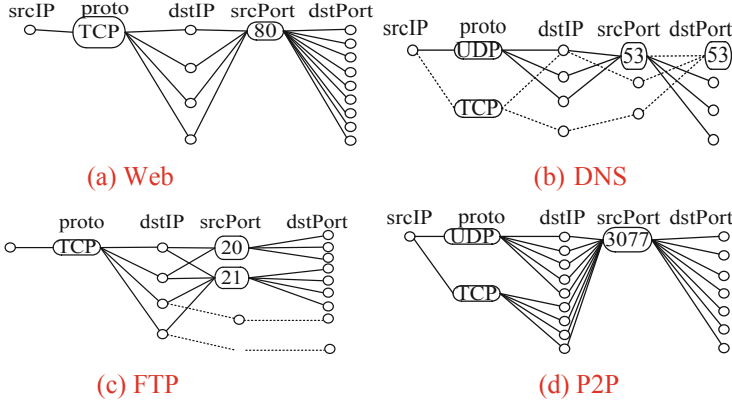
### 2.1 Construction of Power Load Time Series Model

In this paper, the load forecasting algorithm of power grid is studied. Firstly, the time domain signal model of power grid load is given, and the method of signal processing is used to forecast the power grid load. In the construction of network load time series information flow forecasting model, the dispatching model of power grid load is analyzed firstly, and the load data to be analyzed are classified according to five tuples, and the dispatching model of power grid load signal is obtained as shown in Fig. 1.

In the dispatching model shown in Fig. 1, the load sequence is divided into uplink load and downlink load inequality. The statistical characteristic sequence of grid load sequence is obtained as follows:

$$\sum_{i=1}^c \mu_{ik} = 1, k = 1, 2, \dots, n \quad (1)$$

Where,  $k$  is the gray sequence of grid load. The characteristic matching model of power grid load is constructed. According to the fusion results of multiple classifiers, the



**Fig. 1.** Sampling and dispatching model of power grid load signal

information classification is carried out to realize the optimal detection of power grid load. The detection statistics are as follows:

$$V(a_1, \dots, a_m) = \left( a_i^{j-1} \right)_{i,j=1}^m = \begin{pmatrix} 1 & a_1 & \cdots & a_1^{m-1} \\ 1 & a_2 & \cdots & a_2^{m-1} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & a_m & \cdots & a_m^{m-1} \end{pmatrix} \quad (2)$$

$$\mathbf{A} = (a_{i,j})_{i,j=1}^m = \begin{pmatrix} a_{1,1} & \cdots & a_{1,m} \\ \vdots & \ddots & \vdots \\ a_{m,1} & \cdots & a_{m,m} \end{pmatrix} \quad (3)$$

The finite data set model of power grid load signal distribution is constructed, and the energy consumption of power load is as follows:

$$\begin{vmatrix} t_{i_1, j_1} & t_{i_1, j_2} & \cdots & t_{i_1, j_k} \\ t_{i_2, j_1} & t_{i_2, j_2} & \cdots & t_{i_2, j_k} \\ \vdots & \vdots & \ddots & \vdots \\ t_{i_k, j_1} & t_{i_k, j_2} & \cdots & t_{i_k, j_k} \end{vmatrix} \neq 0 \quad (4)$$

The big data statistical analysis model of power grid load is constructed. The clustering analysis and state mining of grid load fusion are carried out by using the distributed detection method of association features. The load operation and maintenance characteristics satisfy the  $V(a_1, \dots, a_m)^{-1}V(b_1, \dots, b_m)$ , covariance matrix satisfies:

$$(V(a_1, \dots, a_m)^{(\alpha_1, \dots, \alpha_m)})^{-1}V(b_1, \dots, b_m)^{(\beta_1, \dots, \beta_m)} \quad (5)$$

According to the above analysis, the power grid load time series sampling model is constructed, and the load classification and clustering processing is carried out according to the information sampling results.

## 2.2 Characteristic Analysis of Power Load

The fusion clustering analysis and state mining of power grid load signal are carried out by using the distributed detection method of association features. The transmission model of power grid load data can be described according to the state characteristics of time series [6]. If the time window function for short-term power load data transmission is  $R_2^T R_2 = V_2 \sum_2 V_2^T$ , and:

$$w(t) = w_{\max} - \frac{\Delta w * t}{t_{\max}} \quad (6)$$

While  $R_2^T R_2 = \{X_{d+1}, X_{d+2}, \dots, X_{d+m}\} \{X_{d+1}, X_{d+2}, \dots, X_{d+m}\}^T$ , the iterations of the Eigenvectors in the power grid load signal state space  $V = [V_1, V_2, \dots, V_m] \in R^{m \times m}$  are minimized. When  $V \in R^{m \times m}$ ,  $VV^T = I_M$  has a minimum value, the correlation dimension eigenvalue function of grid load is obtained as follows:

$$y(t) = \frac{1}{\pi} P \int \frac{x(\tau)}{t - \tau} d\tau = x(t) * \frac{1}{\pi t} \quad (7)$$

The linear superposition of power load series is carried out by using autocorrelation characteristic decomposition, and the time measure information of power grid load is obtained as follows:

$$S_{C/A}(f) = \frac{T_B}{(NT_C)^2} |X(f)|^2 + \sum_{l=-\infty}^{\infty} \sin^2 \left( \pi T_B \left( f - \frac{l}{NT_C} \right) \right) \quad (8)$$

Where in:

$$|X(f)|^2 = T_C^2 N \sin^2(\pi f T_C) |X_{code}(f)|^2 \quad (9)$$

$$X_{code}(f) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x_n \exp(-j2\pi f n T_C) \quad (10)$$

According to the above analysis, the association rules mining and feature analysis of short-term power load in distribution network are realized.

### 3 Optimization of Power Load Classification Clustering Model

#### 3.1 Analysis of Structural Characteristics of Power Grid Load Difference

On the basis of the above-mentioned big data statistical analysis model of power load and the characteristic analysis, the power load classification clustering algorithm is designed. In this paper, the intelligent control optimization method of power load based on state difference clustering is put forward. The fractional Fourier transform matrix of grid load is constructed [7]. By setting the short-term load density parameters (MP and  $\varepsilon$ ) of distribution network first, the discrete data analysis of the forecast value of power grid load is carried out, and it is known that  $\alpha_k \geq 0$ ,  $\sum_{k=1}^K \alpha_k = 1$ , and:

$$G(U|\mu_k, \sum_k) = (2\pi)^{-d/2} \left| \sum_k \right|^{-1/2} \times \exp \left[ -\frac{1}{2} (U - u_k)^T \sum_k^{-1} (U - u_k) \right] \quad (11)$$

Where,  $G(U|\mu_k, \sum_k)$  is the statistical probability density characteristic of short-term power load in distribution network, and the random distribution sequence model of power load time series information flow is as follows:

$$E(e^{-sX}) = \exp \left( -\frac{\sigma^\alpha s^\alpha}{\cos(\pi\alpha/2)} \right) \quad (12)$$

Based on the energy conservation theorem, the acceleration energy function  $E_n$  in the dominant oscillation mode is calculated based on the fuzzy characteristic matching based on the extracted coherent distribution eigenvalues under variable load conditions:

$$E_n = \sum_{m=-\infty}^{\infty} [x(m)w(n-m)]^2 \quad (13)$$

The adjacent sub-module complementary switching modulation search algorithm is used to mine and reconstruct the information characteristics of power grid load [8]. The controlled source USD with AC port is controlled as follows:

$$T_j = \begin{cases} \sigma \sqrt{2 \ln(N)} \left( 1 - \frac{j}{2} \times \frac{E_j}{\sum_{j=1}^j E_j} \right), j=1, 2, \dots, J \\ \sigma \sqrt{2 \ln(N)} \times \frac{E_j}{\sum_{j=1}^j E_j}, j=J+1 \end{cases} \quad (14)$$

Where,  $N$  denotes the length of three-dimensional characteristic sequence of power load and  $J$  is the statistical frequency of power load. The quasi-harmonic oscillator

module is equivalent to RC series circuit [9]. The three-dimensional reconstruction results of power grid load are as follows:

$$\hat{w}_j^k = \begin{cases} \text{sign}(w_j^k) \left( |w_j^k| - \beta \cdot T_j \right), & \text{if } |w_j^k| \geq T_j, j=1, 2, \dots, J+1 \\ 0, & \text{else} \end{cases} \quad (15)$$

Where,  $\beta = e^{-m \times \frac{|w_j^k|^2 - T_j^2}{T_j}}$ ,  $m > 0$ , according to the above analysis, the structural characteristics of power grid load difference are analyzed, and the power load classification fusion and cluster processing are carried out according to the reconstruction results.

### 3.2 State Difference Clustering and Intelligent Control of Power Load

In the high-dimensional phase space, the probability that the correlation dimension index of the information flow time series  $x(t)$  of the power grid load appears in the distributed interval  $i$  is statistically analyzed by clustering the state difference of the power grid load. When the correlation dimension exponential random variable satisfies the discriminant function  $\alpha_k \geq 0$ ,  $\sum_{k=1}^K \alpha_k = 1$ , the output system state function of power grid load signal forecasting is as follows:

$$\begin{cases} x(k+1) = \left( \begin{bmatrix} 1 & 0.6 \\ -0.4 & 0.5 \end{bmatrix} + \begin{bmatrix} 0.02 & 0.01 \\ -0.2 & 0.12 \end{bmatrix} \right) x(k) \\ \quad + \begin{bmatrix} 1 \\ 1 \end{bmatrix} kx(k - \tau_k) + \begin{bmatrix} 0.1 \\ 0.1 \end{bmatrix} w(k) \\ z(k) = [1 \quad 1]x(k) + 0.1u(k) + 0.1w(k) \end{cases} \quad (16)$$

Feature mining and attribute clustering of power grid loads signal are described as:

$$\begin{cases} \dot{x}_1 = x_3 \\ \dot{x}_3 = f_\theta(X, t) + g_\theta(X, t)u(t) + d_\theta(t) \\ \dot{x}_2 = x_4 \\ \dot{x}_4 = f_x(X, t) + g_x(X, t)u(t) + d_x(t) \end{cases} \quad (17)$$

Where,  $X = [\theta, x, \dot{\theta}, \dot{x}]^T$ , based on the fuzzy grid clustering analysis of the association rule set of grid load, the characteristic quantity of grid load is extracted in the phase space [10]. In the finite universe, the distribution of grid area is obtained as follows:

$$T_j = \sigma_j \sqrt{2 \ln(N)}, j = 1, 2, \dots, J+1 \quad (18)$$

$$\sigma_j = \frac{\text{median}(d_j(k))}{0.6745} \quad (19)$$

Where,  $d_j(k)$  denotes the finite characteristic distribution set of grid load, extracts the coherent distribution source feature of grid load, and obtains the fuzzy spread function:

$$\hat{w}_j^k = \begin{cases} w_j^k, & \text{if } |w_j^k| \geq T_j, \\ 0, & \text{else} \end{cases}, j = 1, 2, \dots, J + 1, \quad (20)$$

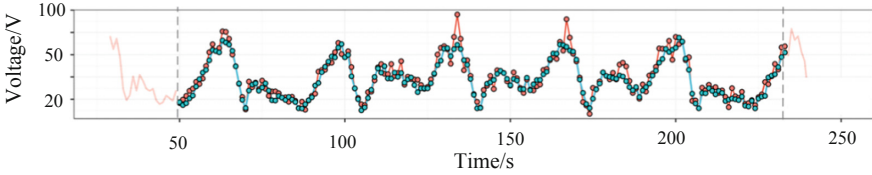
Big data analysis method is used to realize the intelligent control optimization of power grid load [11]. The optimal solution of clustering is as follows:

$$\hat{w}_j^k = \begin{cases} \text{sign}(w_j^k)(|w_j^k| - T_j), & \text{if } |w_j^k| \geq T_j \\ 0, & \text{else} \end{cases} \quad j = 1, 2, \dots, J + 1 \quad (21)$$

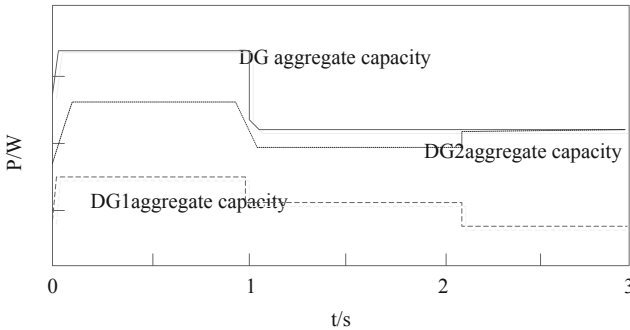
According to the above analysis, the intelligent control optimization of power grid load is realized [12].

### 4 Simulation Experiment and Result Analysis

The intelligent control of power grid load is carried out in Matlab. Assuming the sampling length of data link of power grid load sampling is 2 600, the distribution dimension of load big data is 5, and the spatial sampling delay is 0.12 s. The characteristic distribution of power load dissimilarity in distribution network satisfies the



(a) Voltage distribution



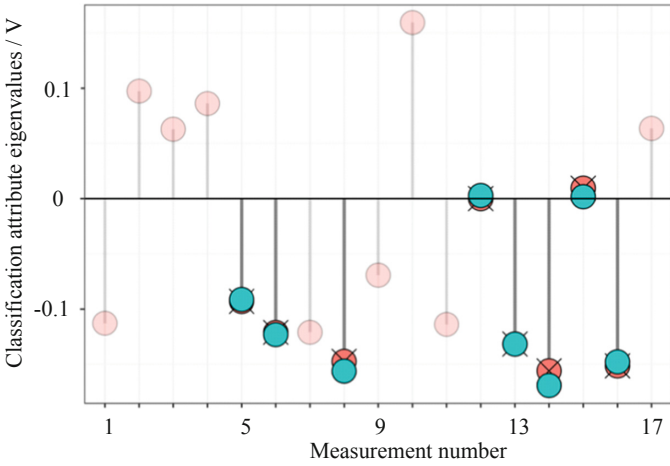
(b) Power distribution of a power load

**Fig. 2.** Sampling results of power load by big data

average value of 0 and the variance of 0.25 is uniform normal distribution. The sampling frequency of power load is  $f_1 = 0.3, f_2 = 0.05$ , to classify and cluster the load according to the above simulation parameters. The power and voltage amplitudes of the power load are measured and the results are shown in Fig. 2.

Figure 2 shows the load power distribution between different DG units. It can be seen from the figure that the DG system can automatically adjust the power generation according to the load power from 0 to 2.0 s, and different DG units can automatically distribute the load power according to their maximum power. At 2.0 s, the DG2 unit fails, and the normally operating DG unit quickly adjusts the power generation to ensure normal power supply for critical loads. It is worth noting that if the normal power supply of the load cannot be satisfied at this time, the control can be taken after the load shedding operation is performed according to the priority of the load.

Taking big data of power grid load in Fig. 2 as the test object, the clustering results are obtained as shown in Fig. 3.



**Fig. 3.** Classification and clustering output of short-term Power load in distribution network

The analysis of Fig. 3 shows that the clustering method of short-term power load in this paper has a good characteristic convergence, and the error rate of classification of short-term power load in distribution network is tested by different methods. The comparison results are shown in Table 1, from which we can see that the classification of short-term power load in distribution network can be classified by different methods. In this paper, the classification of short-term power load in distribution network is classified by this method, and the misdivision rate is low.

**Table 1.** Comparison of error rates.

Iterations	Proposed method	Reference [4]	Reference [5]
100	0.113	0.198	0.242
200	0.023	0.145	0.211
300	0.015	0.089	0.178
400	0	0.045	0.102

## 5 Conclusions

In this paper, an intelligent control optimization method based on the state difference clustering is proposed, and the big data statistical analysis model of the power grid load is constructed. The clustering analysis and state mining of grid load are carried out by using the distributed detection method of association features, and the regression analysis model of grid load state difference is constructed to realize the state differential clustering of power grid load signal in high-dimensional phase space. Based on the classification and fusion of the extracted characteristic sets of grid load, big data analysis method is used to optimize the intelligent control of power grid load signal. The simulation results show that the proposed method has better accurate classification performance and lower misdivision rate, which improves the output stability of power grid load. This method has a good application value in the intelligent control of power grid load.

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