Fault Feature Analysis of Power Network Based on Big Data

Cai-yun Di(✉)

State Grid Jibei Electric Power Company Limited Skills Training Center, Baoding Technical College of Electric Power, Baoding, China
cjj998799@163.com

Abstract. During the operation of the power network, there was a sharp change in current and voltage at the time of failure, which made it difficult for the grid operators to quickly and accurately determine the fault. This paper proposed a big data-based power network fault feature analysis method design. Taking the symmetrical fault component method as the main analysis method, a two-phase short-circuit equivalent model was constructed by accurately analyzing the fault characteristics of the power network, and the fault features were detected and located by the big data network preprocessor. The experimental results shown that the big data power network fault feature analysis method could effectively feedback and locate the fault location and complete the maintenance of the power network in time.

Keywords: Big data environment · Power network · Fault characteristics · Analytical method

1 Introduction

With the increase of the scale of power networks, the safe operation of power grids is becoming more and more important to society [1]. However, due to the frequent occurrence of natural disasters in China and the aging of power equipment, power grid failures are inevitable and bring losses to the economy and residents' lives. Therefore, it is necessary to study the characteristics of power network faults before, during and after the fault to effectively avoid faults and quickly eliminate faults. By means of the symmetrical component method, the principle of current and voltage characteristics of typical faults of 220 kV and above power grids is analyzed and summarized, and the fault feature quantities of the multiple center electrical network are transformed into a single comprehensive feature quantity to monitor the operating state of the distribution network [2]. The fault area can be determined and located according to the association situation of each node and the size of the local anomaly factor. A two-phase short-circuit equivalent model is established, and the big data network preprocessing is used to improve the accuracy and reliability of the fault analysis of the power network. Through the method of experimental argumentation analysis, the effectiveness of the big data power network fault feature analysis method designed in this paper is determined. During the failure analysis, the fault location can be effectively feed backed and located, and the maintenance of the power network can be completed in time.

G. Gui and L. Yun (Eds.): ADHIP 2019, LNICST 301, pp. 143–151, 2019.
https://doi.org/10.1007/978-3-030-36402-1_15

2 Analytical Method Design

The analysis method designed in this paper shows the fault processing process of power network as shown in Fig. 1. It is divided into four parts: symmetric fault component [3], two short-circuit equivalent models and big data preprocessing.

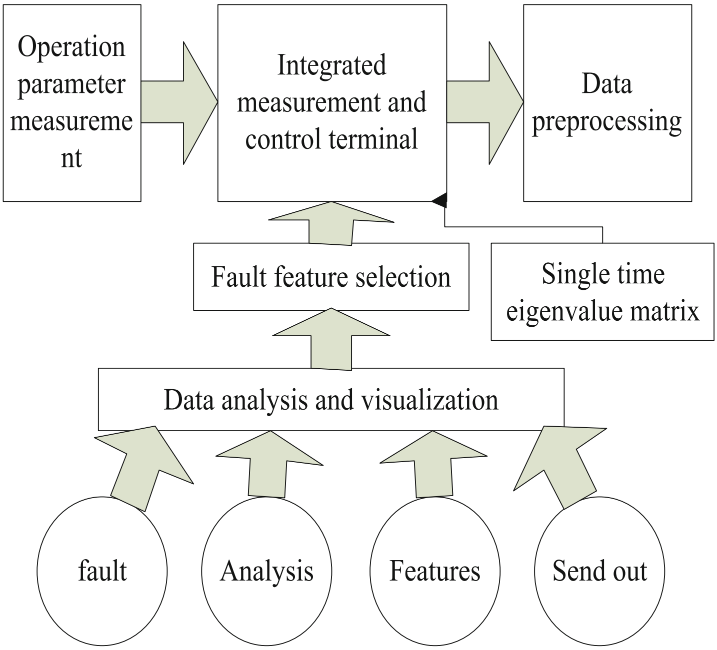

Fig. 1. Process of fault feature analysis method

2.1 Symmetric Fault Component Design

Most of the faults in the power grid are asymmetric faults (single-phase, two-phase grounding, etc.). When this type of fault occurs in the power grid [4], the current and voltage at the fault point are no longer symmetrical, and a symmetrical component method is needed to perform the short circuit calculation.

The symmetrical component method is a basic method for analyzing the asymmetric operating state of a symmetric system. Any asymmetric three-phase phasor $\boldsymbol{F}_{\mathrm{a}}$, $\boldsymbol{F}_{\mathrm{b}}$, $\boldsymbol{F}_{\mathrm{c}}$ can be decomposed into three sets of symmetric components with different phase sequences: positive sequence component $\boldsymbol{F}_{\mathrm{a}(1)}$, $\boldsymbol{F}_{\mathrm{b}(1)}$, $\boldsymbol{F}_{\mathrm{c}(1)}$; negative sequence component $\boldsymbol{F}_{\mathrm{a}(2)}$, $\boldsymbol{F}_{\mathrm{b}(2)}$, $\boldsymbol{F}_{\mathrm{c}(2)}$; zero sequence component $\boldsymbol{F}_{\mathrm{a}(0)}$, $\boldsymbol{F}_{\mathrm{b}(0)}$, $\boldsymbol{F}_{\mathrm{c}(0)}$. That is, the following relationship exists:

$$\left.\begin{aligned} \boldsymbol{F}_a &= \boldsymbol{F}_{a(1)} + \boldsymbol{F}_{a(2)} + \boldsymbol{F}_{a(0)} \\ \boldsymbol{F}_b &= \boldsymbol{F}_{b(1)} + \boldsymbol{F}_{b(2)} + \boldsymbol{F}_{b(0)} \\ \boldsymbol{F}_c &= \boldsymbol{F}_{c(1)} + \boldsymbol{F}_{c(2)} + \boldsymbol{F}_{c(0)} \end{aligned}\right\} \tag{1}$$

The symmetrical component method is cited in the calculation of the imbalance of the power network system [5], that is, any three-phase unbalanced current, voltage or impedance is decomposed into three balanced phasor components, i.e., positive phase sequence ($\boldsymbol{U}_{U1}$, $\boldsymbol{U}_{V1}$, $\boldsymbol{U}_{W1}$); negative phase sequence ($\boldsymbol{U}_{U2}$, $\boldsymbol{U}_{V2}$, $\boldsymbol{U}_{W2}$) and zero phase sequence ($\boldsymbol{U}_{U0}$, $\boldsymbol{U}_{V0}$, $\boldsymbol{U}_{W0}$).

$$\left.\begin{aligned} \boldsymbol{U}_U &= \boldsymbol{U}_{U1} + \boldsymbol{U}_{U2} + \boldsymbol{U}_{U0} \\ \boldsymbol{U}_V &= \boldsymbol{U}_{V1} + \boldsymbol{U}_{V2} + \boldsymbol{U}_{V0} \\ \boldsymbol{U}_W &= \boldsymbol{U}_{W1} + \boldsymbol{U}_{W2} + \boldsymbol{U}_{W0} \end{aligned}\right\} \tag{2}$$

The phase sequence of the positive phase sequence (clockwise direction) is equal to $\boldsymbol{U}_{U1}$, $\boldsymbol{U}_{V1}$, $\boldsymbol{U}_{W1}$ and equal in size, 120° apart; The phase sequence of the negative phase sequence (counterclockwise direction) is $\boldsymbol{U}_{U2}$, $\boldsymbol{U}_{V2}$, $\boldsymbol{U}_{W2}$ in order, equal in size, 120° apart; The zero phase sequence is equal in magnitude and in phase [6]. The operator a is quoted in the symmetrical component method, which is defined by the fact that the unit phasor is rotated 120° counter clockwise, then:

$$\left.\begin{aligned} \boldsymbol{U}_{U0} &= \frac{1}{3}\boldsymbol{U}_U + \boldsymbol{U}_V + \boldsymbol{U}_W \\ \boldsymbol{U}_{U1} &= \frac{1}{3}\boldsymbol{U}_U + a\boldsymbol{U}_V + a^2\boldsymbol{U}_W \\ \boldsymbol{U}_{U2} &= \frac{1}{3}\boldsymbol{U}_U + a^2\boldsymbol{U}_V + a\boldsymbol{U}_W \end{aligned}\right\} \tag{3}$$

In the above calculations, all are based on the $\boldsymbol{U}$ phase, and are vector calculations.

2.2 Construction of Two-Phase Short-Circuit Equivalent Model

The double instantaneous fault in the face of current and voltage is the same as the fault current and voltage characteristics in a single phase for a short time [7]. The difference is that there is still a fault current after the fault phase switch is overlapped, and the coincidence is unsuccessful, and the switch three-phase trips, as shown in Fig. 2.

According to the analysis of Fig. 2, the current and voltage characteristics of the phase-to-phase unground fault are as follows: the fault current of the two fault phases is large, and the fault current of the non-fault phase is zero; The non-fault phase voltage is equal to the pre-fault voltage [8], the fault voltage amplitude is reduced by half; the zero sequence current is zero.

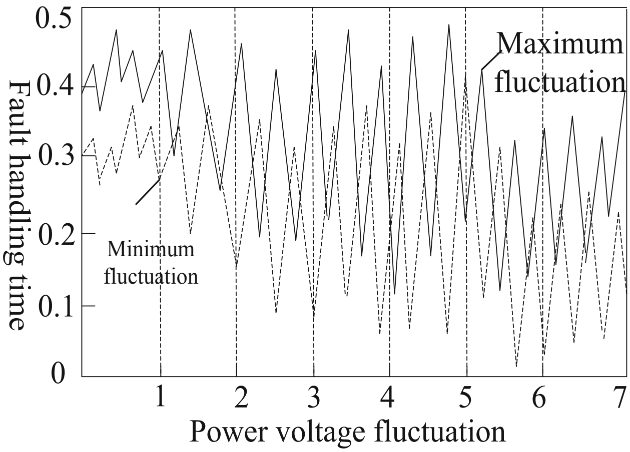

Fig. 2. Instantaneous ground fault recording

The two-phase short-circuit equivalent model construction steps are as follows:

Assuming that the V, W phase is short-circuited by two phases, the voltage at the fault point three relative to ground and the phase current flowing out of the point (short-circuit current) have the following boundary conditions:

$$\left.\begin{aligned} \boldsymbol{U}_{fu} &= 0 \\ \boldsymbol{I}_{fu} &= 0 \\ \boldsymbol{I}_{fv} &= -\boldsymbol{I}_{fw} \end{aligned}\right\} \tag{4}$$

According to formula (3), the conversion is as follows:

$$\begin{bmatrix} \boldsymbol{I}_{f(1)} \\ \boldsymbol{I}_{f(2)} \\ \boldsymbol{I}_{f(0)} \end{bmatrix} = \frac{1}{3}\begin{pmatrix} 1 & a & a^2 \\ 1 & a^2 & a \\ 1 & 1 & 1 \end{pmatrix}\begin{bmatrix} 0 \\ \boldsymbol{I}_{fv} \\ -\mathrm{I}_{fv} \end{bmatrix} = \frac{j\boldsymbol{I}_{fv}}{\sqrt{3}}\begin{bmatrix} 1 \\ -1 \\ 0 \end{bmatrix} \tag{5}$$

The above process shows that there is no zero sequence current at the two-phase short-circuit fault point.

Combine the composite network diagram and the formulas (1) and (5) to obtain:

$$\boldsymbol{I}_{fv} = -j\sqrt{3}\frac{\boldsymbol{U}_{f|0|}}{\mathrm{Z}\sum(1)+\mathrm{Z}\sum(2)} \tag{6}$$

$$\boldsymbol{I}_{fw} = j\sqrt{3}\frac{\boldsymbol{U}_{f|0|}}{\mathrm{Z}\sum(1)+\mathrm{Z}\sum(2)} \tag{7}$$

It can be seen that when the positive sequence impedance is equal to the negative sequence impedance, the non-fault phase voltage is equal to the pre-fault voltage, and the fault phase voltage amplitude is reduced by half.

The technical support system for power network fault analysis is based on two-phase short circuit, supplemented by energy management system [9]. At the same time, it provides fault characteristics for the control center of power equipment, and completes the construction of the two-phase short-circuit equivalent model. Figure 3 shows the two-phase short-circuit equivalent model structure.

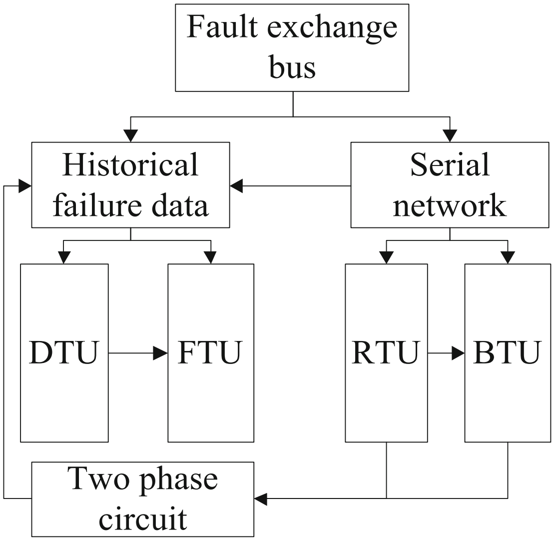

Fig. 3. Two-phase short-circuit equivalent model structure

2.3 Big Data Network Preprocessing

The big data network pre-processing is used to perform preliminary screening and pre-processing on the raw data uploaded by each sensing device, reducing the amount of irrelevant data and generating the required initial feature quantity matrix. This part mainly includes selecting the fault feature quantity, constructing the correlation matrix, and processing the area difference [10]. In the process of selecting the fault feature quantity, the electrical characteristic quantity selected in this paper is current and power. Among them, three-phase current, negative sequence current, and zero-sequence current and corresponding power or no power are covered.

The association matrix is constructed, the process is: First, each terminal node E_j in the distribution network is numbered, and the area Z_j between the nodes is also numbered, and finally the matrix is constructed according to the rules shown in Table 1.

Table 1. Building a big data network matrix rule.

Correlation value	Association relationship
−1	The node is located in the area, but the current power of the node is directed outside the region
0	Nodes are not in the region
1	The node is located in the area, and the current power of the node points to the region

The purpose of processing the area difference is mainly to amplify the difference between the fault and the normal node to facilitate fault identification. Specific steps are as follows:

The regional difference matrix R_i corresponding to each feature quantity is calculated and obtained:

$$R_i = AT_i \tag{8}$$

Where: A represents the network association matrix; T_i represents the column matrix. The matrix is composed of feature amount data uploaded by each node terminal.

Fault monitoring matrix C_i is established(single feature quantity under single time period):

$$C_i = \left|A^T\right| R_i \tag{9}$$

The state monitoring matrix of each feature quantity in a single time period (take one power frequency cycle as the time length and sample 64 times) [11], spatially expands into a related state monitoring matrix W_i = (i = 0–19) of multiple electrical feature quantities, and further merge into a multiple time and multiple electrical feature quantity high-dimensional spatiotemporal state monitoring matrix W:

$$\begin{aligned} W_i &= [C_1 C_2 \cdots C_w] \\ W &= [W_1 W_2 \cdots W_W] \end{aligned} \tag{10}$$

3 Experimental Argumentation Analysis

In order to verify the feasibility of the fault analysis method designed in this paper, a 10 kV smart distribution network with dual DG is taken as the research object, as shown in Fig. 4.

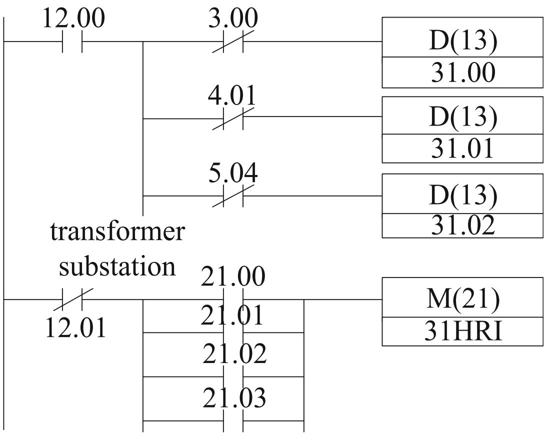

Fig. 4. Power network topology diagram

Figure 5 shows a visual analysis of multidimensional scaling and corresponding LOF values for normal operation of the distribution network. It can be seen that under normal operating conditions, there are no outliers, and each node (1–17, 17 is a generalized node) is similar. The dimensionality reduction result in Fig. 5 is expressed as a point-like area at the origin of the coordinates, and the LOF values are all in the vicinity. According to the decision rule, there is no fault in the distribution network at this time.

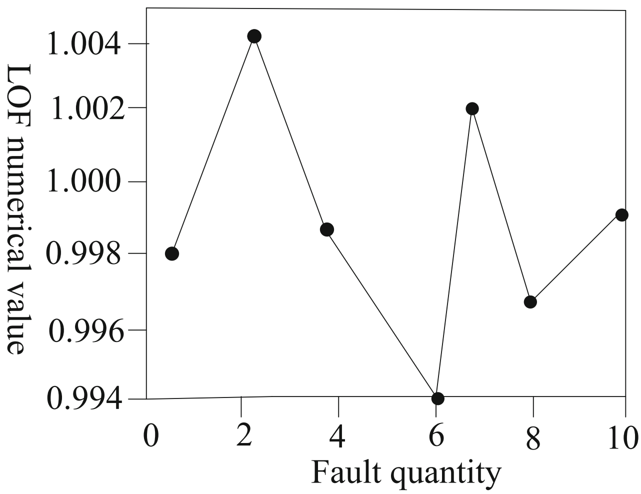

Fig. 5. Grid fault monitoring data in the operating state

Figure 6 shows a visual analysis of the multiple dimensional dimensionality reduction and corresponding LOF values for a single-phase ground fault in the Z11 feeder section. Among them, 13 and 14 physical nodes and generalized nodes (17) are all outliers, and the corresponding LOF value reaches about 96.

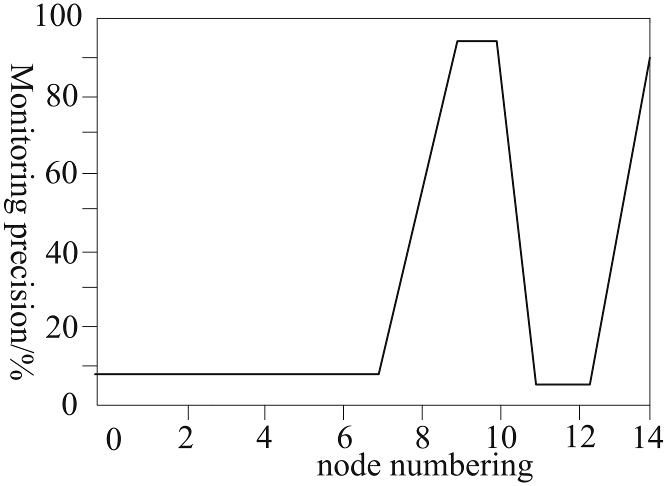

Fig. 6. Z11 feeder section fault monitoring data

By analyzing the graphs of Figs. 5 and 6, it is determined that the relevant fault of the power network has occurred, and the fault is located in the Z11 region where the nodes 13, 14 are located. The data processing center sends a trip command to the faulty node terminal in time to isolate the Z11 area. In addition, this paper also tests the power failure test caused by the failure of the node sensor and the failure of the bus node Z2 area (two-phase grounding). Compared with the traditional fault analysis method, the experimental results show that the big data-based power network fault feature analysis method is effective in monitoring and locating, and can timely and effectively report and locate the fault of the power network.

4 Conclusions

This paper analyzes the characteristics of power network faults in big data environment, and builds the component relationship with symmetric faults based on fault characteristics. Furthermore, a two-phase short-circuit equivalent model is constructed, and the preprocessing of the big data network is used to effectively detect and locate the fault features. The experimental demonstration shows that the fault feature analysis method designed in this paper has extremely high effectiveness. While completing the monitoring and positioning of the fault characteristics of the power network, it effectively reports and locates the fault location and completes the maintenance of the power network in time. It is hoped that the research in this paper can provide theoretical basis and reference for the analysis method of fault characteristics of power network in China.

References

1. Zhu, Y., Li, L., Song, Y., et al.: Large data storage and parallel processing methods for power equipment monitoring based on ODPS platform. J. Electr. Technol. **32**(9), 199–210 (2017)
2. Chai, Q., Zheng, W., Pan, J., et al.: Research on state monitoring and fault processing of intelligent distribution network based on large data analysis. Mod. Electr. Technol. **16**(4), 105–108 (2018)
3. Lei, W., Qing, C., Gao, H., et al.: Intelligent substation fault tracking architecture based on large data mining. Power Syst. Autom. **56**(3), 84–91 (2018)
4. Wang, S., Zhao, D.: Review and prospect of power grid fault diagnosis. Autom. Electr. Power Syst. **41**(19), 164–175 (2017)
5. Wei, H., Le, Z., Yong, M., et al.: Study on post-fault transient stability assessment of power system based on in-depth learning. Power Grid Technol. **26**(10), 40–46 (2017)
6. Yu, Y., Zhu, Z., Huang, C., et al.: Distribution network fault trend judgment based on large data analysis. Power Supply Technol. **23**(1), 132–134 (2018)
7. Ge, X., Ai, M., Li, Z., et al.: Large data ETL method of distribution network operation monitoring signal based on CEP engine. New Technol. Electr. Energy **36**(9), 36–42 (2017)
8. Li, G., Yu, C., Liu, Y., et al.: Power transformer fault prediction and health management: challenges and prospects. Power Syst. Autom. **41**(23), 156–167 (2017)
9. Wang, D., Li, J.: Query optimization method for large data of condition monitoring of substation equipment. Power Syst. Autom. **41**(2), 165–172 (2017)
10. Wang, Y., Jia, Y.: Improved matrix algorithm for fault location of distribution network containing distributed generation. Comput. Simul. **35**(04), 58–64 (2018)
11. Hao, S., Ming, L., Ma, H., et al.: Research on large data application planning method in power supply chain. China Electr. Power **50**(6), 69–74 (2017)