

# Fault type Identification of Distribution Network Based on Transient Current Sequence Component

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**Abstract**—Aiming at the occurrence of line fault in distribution network, an intelligent identification method of fault type is developed, which is of great significance for rapid fault line selection and location. When different types of faults occur in the 35kV low-current grounding system, different transient currents will be generated. Therefore, a fault identification method based on transient current monitoring is proposed. FTU (Feeder Terminal Unit) was used to obtain transient current, and then symmetric component method was used to decompose transient current. The amplitude of positive, negative and zero sequence current obtained was used to construct probability neural network (PNN) for training. The test samples are brought into the PNN network, and the simulation results show that the fault identification method has high accuracy.

**Keywords**—distribution network; fault type; fault characteristic quantity; neural network; fault identification

## I. INTRODUCTION

With the continuous development of science and technology, people become more and more dependent on electricity. If power line fault occurs, there is a kind of fault type recognition device, can make maintenance personnel in a timely manner to judge the fault types, quickly restore power is of great significance to improve the system. In the paper<sup>[1]</sup>, the frequency analysis of the wavelet transform is used to determine the fault of the power grid line, but the conversion process is relatively sophisticated, and the application of the application in engineering is still pending. Aiming at the characteristics of zero sequence current and transient current in the fault of distribution network, this paper presents a method to distinguish fault types based on transient current. FTU (Feeder Terminal Unit) was used to obtain transient current information<sup>[2]</sup>. Then, in MATLAB environment, symmetrical component method was used to simulate and analyze the faults of distribution network in different categories, and the amplitude of each characteristic sequence component was obtained. Finally, the extracted feature sequence components are trained by neural networks, which can accurately distinguish different distribution network fault types.

## II. THEORETICAL ANALYSIS OF TRANSIENT CURRENT SEQUENCE COMPONENTS

### A. Method for Calculating the Transient Current Sequence Component

The three-phase current and voltage are no longer symmetrical when the single-phase ground fault occurs in the distribution network. In most cases, the symmetric component method<sup>[3]</sup> is adopted to analyze the asymmetric fault problem, that is, the symmetric three-phase vector is decomposed by a set of asymmetric three-phase phasor transformation methods, so as to obtain the positive, negative and zero sequence components of the transient current (that is  $I_{a1}, I_{a2}, I_{a0}$ ). When a phase is taken as the reference phase, the relationship between the asymmetric three-phase phasor and its symmetric components can be obtained as follows:

$$\begin{bmatrix} \dot{I}_{a1} \\ \dot{I}_{a2} \\ \dot{I}_{a0} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & a & a^2 \\ 1 & a^2 & a \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix} \quad (1)$$

### B. Sequence Component of Single-phase Grounding Fault

Taking the grounding short circuit fault of phase A as an example, the three boundary conditions at the fault point are expressed as symmetric components:

$$\begin{cases} \dot{V}_a = \dot{V}_{a1} + \dot{V}_{a2} + \dot{V}_{a0} = 0 \\ \dot{I}_b = a^2 \dot{I}_{a2} + a \dot{I}_{a1} + \dot{I}_{a0} = 0 \\ \dot{I}_c = a \dot{I}_{a1} + a^2 \dot{I}_{a2} + \dot{I}_{a0} = 0 \end{cases} \quad (2)$$

THE network element is represented by reactance, and each sequence network can be expressed as:

$$\begin{cases} \dot{V}_{a_1} = \dot{E}_\Sigma - j X_{1\Sigma} \dot{I}_{a_1} \\ \dot{V}_{a_2} = -j X_{2\Sigma} \dot{I}_{a_2} \\ \dot{V}_{a_0} = -j X_{0\Sigma} \dot{I}_{a_0} \end{cases} \quad (3)$$

In (3),  $X_{1\Sigma}$  is positive sequence impedance,  $X_{2\Sigma}$  is negative sequence impedance,  $X_{0\Sigma}$  is zero sequence impedance. Simultaneous (1)(2)(3), positive, gative and zero sequence current can be obtained as follows:

$$\dot{I}_{a_1} = \dot{I}_{a_2} = \dot{I}_{a_0} = \frac{\dot{E}_\Sigma}{j(X_{1\Sigma} + X_{2\Sigma} + X_{0\Sigma})} \quad (4)$$

In the fault port, connect the sequence networks according to boundary conditions to obtain the composite sequence network as shown in figure. 1:

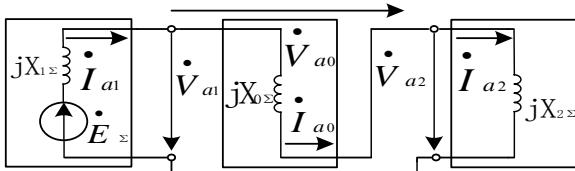


FIGURE I. COMPOSITE SEQUENCE NETWORK OF SINGLE-PHASE GROUND FAULT

By the (4), (5) and figure 1 composite sequence network, when single-phase earth fault in power distribution network system, there is a clear positive, negative and zero sequence current, but in the literature [4], it is proposed that the magnitude of zero sequence and negative sequence current will be affected by the operation mode of neutral point and transition resistance of the system. So in the actual operation of distribution network amplitude of positive, negative and zero sequence current are not necessarily equal [5]. Similarly, when two-phase short-circuit and two-phase short-circuit grounding occur in the system, symmetric component method can be used to solve such asymmetric problems, so as to obtain the corresponding positive, negative and zero sequence current amplitude, which will not be repeated here.

### III. IDENTIFICATION OF FAULT TYPES

#### A. Principle of PNN

PNN network is an artificial neural network model based on Bayes classification rule and probability density function estimation method of Parzen window. When applied to practical classification problems, it can use linear algorithm to complete the task and has the characteristics of high precision of nonlinear algorithm, which makes the network widely used in various fields of classification problems. PNN network is a radial basis network with the minimum risk criterion of yeas as the theoretical basis and has developed into a feedforward neural network. The hierarchical models of the PNN have four

layers, which are input layers, pattern layers, summing layers, and output layers, respectively. Each of the pattern layers is output by the formula (5):

$$f(\mathbf{X}, \mathbf{W}_i) = \exp \left[ \frac{-(\mathbf{X} - \mathbf{W}_i)^T (\mathbf{X} - \mathbf{W}_i)}{2\delta^2} \right] \quad (5)$$

In (6),  $\mathbf{W}_i$  represents weights from the input layer to the pattern layer;  $\delta$  represents a smoothing factor that is important for classification.

In the summation layer, each summation layer element is not only associated with its own category of pattern layer elements, but according to formula (5), the probability density function is obtained by summing the probabilities its own category, so that the estimation probability density function only belongs to this category. The output layer is essentially a competitive element layer, whose function is to accept the probability density function of the summation layer and select the largest one as the output, so as to complete the classification of samples.

#### B. PNN Fault Type Recognition

In this paper, the symmetrical component method is used to decompose the three-phase transient current, it will obtain the fault characteristic quantity of positive sequence, negative sequence and zero sequence current. After the characteristic quantities are trained by PNN network, the existing fault characteristic quantities are put into the established PNN to obtain the fault types of distribution network system. Therefore, this model has three input points, which respectively means the amplitudes of three fault characteristic quantities. There are four output nodes, which respectively represent three distribution network fault types and one "normal" state. The number of nodes and neurons in the mode layer and summation layer are determined by the number of samples involved in training. According to this idea, the network structure diagram in figure2 can be obtained.

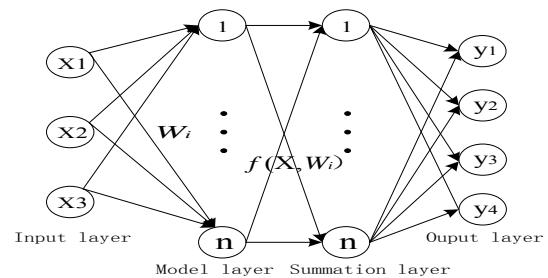


FIGURE II. STRUCTURE OF PROBABILISTIC NEURAL NETWORK

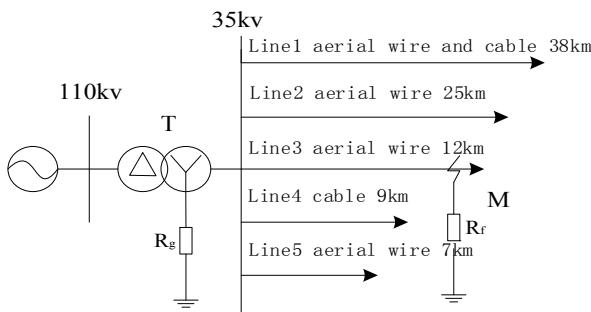


FIGURE III. STRUCTURE DIAGRAM OF LOW-CURRENT GROUNDING SYSTEM

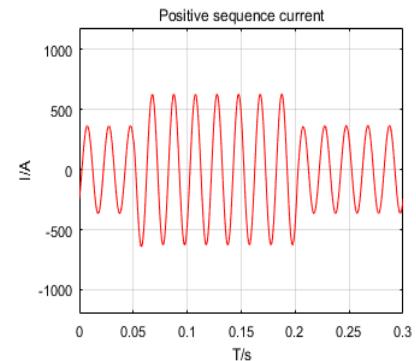
#### IV. SIMULATION MODEL

##### A. Simulation Analysis

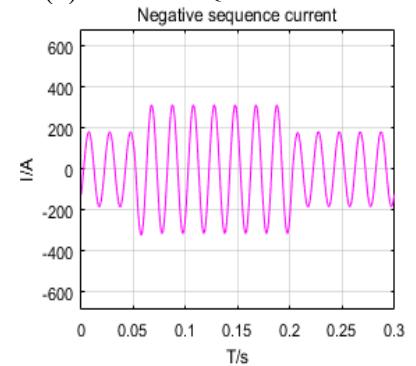
Combining with the theoretical analysis of the fault characteristics of distribution network in the previous paper, a 35 kV low current grounding system is built by using MATLAB. It can simulate single-phase grounding fault, two-phase short-circuit, two-phase short-circuit and grounding fault. In Figure3 (in the previous page),  $R_f$  denotes transition resistance and  $R_g$  denotes ground resistance. The main parameters are set as follows: the positive and zero sequence impedance of overhead wire resistance is [0.03689Ω/km, 0.4276Ω/ km], the inductance of the positive sequence and zero sequence impedance is [1.3570 mH/km, 5.4146mH/km], the capacitance of the positive sequence and zero sequence impedance is [3.2174 nF, 10.3865 nF]; Finally, Considering the actual distribution network system, all loads are not linear loads, in order to be closer to the actual distribution network system, the simulation model adopts the nonlinear three-phase Parallel RLC Load.

##### B. Extraction of Fault Feature Quantity

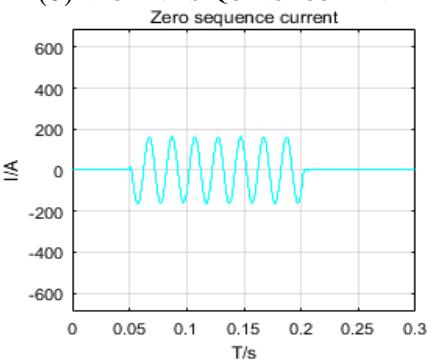
The fault current waveform obtained from the simulation of distribution network is processed to extract the fault characteristic quantity. Taking M-point A-phase non-metallic grounding as an example, the time of failure is 0.05s, troubleshooting time is 0.2s and the total simulation time is 0.3s. Three-phase fault current signal is input into subsystem module (The module is encapsulated by symmetrical component method) at the same time. It will get positive sequence, negative sequence and zero sequence components are shown in figure 4 below. Finally, the fault feature is imported into workspace to prepare for training with neural network algorithm



(a) POSITIVE SEQUENCE CURRENT



(b) NEGATIVE SEQUENCE CURRENT



(c) ZERO SEQUENCE CURRENT

FIGURE IV. AMPLITUDE OF CHARACTERISTIC COMPONENTS UNDER SINGLE-PHASE GROUNDING FAULT

##### C. Identification of Fault Types

The program of this project is composed of two modules: training data and diagnosis. The data sample is a 44-dimensional matrix, and amplitude of positive, negative and zero sequence currents listed in the first three characteristic quantities (due to limited space, only 8 samples are taken in the table). The fourth one is the output of fault category. Among them, "1" represents single-phase ground fault, "2" represents two-phase short-circuit fault, "3" represents two-phase ground fault, and "4" represents normal state. The corresponding relationship between amplitude of various characteristic sequence components and fault types is shown in table 1(in the next page).

SPREAD, as the distribution density, has a certain impact on the performance of the network<sup>[6]</sup>. So, on the basis of the

same number of training samples and test samples, 11 units of characteristic sequence components of each fault type were selected, and there were 4 fault categories, so a total of 44 samples were taken. Use any 33 samples as training sample Train=data(1:33,:);input, and take the remaining data Test=data(34:end,:); as test samples into the trained network, Meanwhile, Setting SPREAD as 1, 1.5, 2, 2.5, 3, 3.5 and 4 for simulation analysis, when SPREAD=3, PNN network will get the best fault identification rate, and then Y=sim(net, p test) function is used. The effect diagram of the test sample classification can be obtained as shown in figure 5.

TABLE I. RELATIONSHIP BETWEEN FAULT TYPE AND FEATURE QUANTITY.

Sample number	Positive sequence amplitude	Negative sequence amplitude	Zero sequence amplitude	Fault type
1	1051.980	629.025	0	2
2	610.094	72.910	95.575	1
3	594.209	136.363	21.243	3
4	546.2409	0	0	4
5	548.277	55.779	14.98	3
6	594.641	52.642	69.032	1
7	954.404	474.095	78.179	3
8	616.983	170.928	0	2

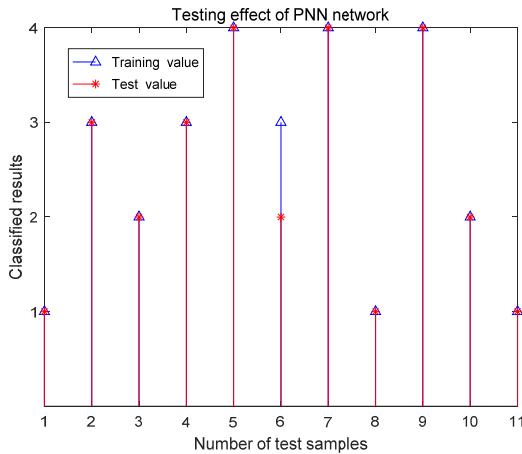


FIGURE V. EFFECT DIAGRAM OF TEST DATA CLASSIFICATION

As can be seen from the figure, when the test sample is brought into the trained PNN network, only one sample is a fault type judgment error of the power system, indicating that the PNN network established by us has a high fault identification accuracy.

## V. CONCLUSION

In this paper, the magnitude of positive sequence, zero sequence and negative sequence currents of transient current are selected as the characteristic quantities to distinguish fault types. Compared with the single zero-sequence current or negative-sequence current used in the past, its fault diagnosis accuracy is higher. In addition, the symmetric component method is used to decompose the transient current, getting the order component easily. Therefore, its application prospect is considerable.

## ACKNOWLEDGMENT

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