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Overview of Mechanical Fault Diagnosis Methods for High Voltage Circuit Breakers

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Abstract

Mechanical failure is the main part of the high-voltage circuit breaker operation failure. The safe and normal operation of the high-voltage circuit breaker is one of the key parts of the power grid operation. In recent years, research on the failure of high-voltage circuit breakers has focused on the rapid and accurate diagnosis of faults. This paper introduces the basic diagnosis process of mechanical faults of high voltage circuit breakers and reviews the technology of circuit breaker fault diagnosis in the past five years. Finally, the idea of mechanical fault diagnosis of high voltage circuit breakers is discussed, and the future development prospects.

Keywords

High voltage circuit breaker; Mechanical fault; Fault diagnosis.

1. INTRODUCTION

High-voltage circuit breakers are one of the most important equipment in power production activities. They can protect and control other power equipment. Once the circuit breaker is running, it will cause great losses.

The timely diagnosis of high-voltage circuit breaker faults can effectively avoid further expansion of losses. According to the statistics of the international large power grid conference and the relevant domestic departments on the fault of the high voltage circuit breaker, it is indicated that the fault caused by the mechanical performance is 70% of the fault in the operation of the circuit breaker; 19% caused by the electrical fault of the auxiliary circuit and the control circuit; The fault caused by the insulation problem accounts for 8.3%, and the fault caused by other causes accounts for 2.7% [1-5].

At present, the research on fault diagnosis of high-voltage circuit breaker mainly focuses on the vibration signal and current signal of high-voltage circuit breaker in the switching process.

For the acquisition of the vibration signal, the vibration sensor is generally placed in the collection part, and the vibration signal generated during the opening and closing operation of the circuit breaker is collected; for the current signal, the current of the coil is collected by the current sensor during the closing process. The collected data is transmitted to computer software through the data acquisition card for the next processing.

The mechanical fault diagnosis of high voltage circuit breakers is roughly divided into three main processes: signal preprocessing, feature extraction and fault identification classification. It mainly extracts the corresponding fault feature quantity by reconstructing the signal, and then identifies and classifies the fault.

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2. SIGNAL PREPROCESSING

2.1. Wavelet Decomposition

Wavelet decomposition is to decompose the signal with noise step by step according to the principle of the discrete wavelet transform. The input signal is decomposed into two parts, high frequency, and low frequency. After decomposition, high-frequency components are removed by selecting thresholds, smooth components are retained and signals are reconstructed.

Wavelet decomposition has variable time-frequency resolution, high-frequency resolution and low time resolution in a low-frequency band, high time resolution and low-frequency resolution in a high-frequency band. It can effectively achieve the purpose of extracting useful signals and removing interference.

The literature [6-8] uses a wavelet to decompose the signal and obtains better results.

2.2. Zero Phase Digital Filtering

The zero-phase digital filter is improved on the traditional frequency-domain filter, and the zero-phase offset of the filter result is achieved by using the way that the phase shift of the forward data sequence and the reverse data sequence cancel each other when passing through the filter, which can effectively improve the phase shift characteristic of the frequency domain filter. Compared with the wavelet decomposition and reconstruction non-stationary signal processing method without phase shift, the cut-off frequency is clear and the computation is small, which is suitable for processing amplitude modulation signal and frequency modulation signal.

In [9], the zero-phase filtering method is used to process the vibration signal, which overcomes the problem of large calculation of wavelet packet decomposition and reconstruction method.

2.3. Morphological Filtering

Mathematical morphology is a nonlinear filtering algorithm, which is simple and fast. In recent years, it has been used more and more in signal analysis. The basic principle is based on the geometric features of signals, and the edge contour information of signals is extracted by using predefined structural elements or structural elements corresponding to signal components, and the main morphological features of signals are maintained. The basic operators of morphology include corrosion, expansion, morphological opening and morphological closing.

In [10], the noise filtering of the coil current of the high voltage circuit breaker is completed by a morphological opening and closing weighted composite filtering algorithm of a double structural element.

3. FEATURE EXTRACTION

3.1. Current Signal

The closing and closing coil are one of the important components in the operating mechanism of a high voltage circuit breaker. When the current passes through the coil, the flux will be generated in the electromagnet, and the moving core will be attracted by the magnetic force, making the circuit breaker open and close. At present, the research on the mechanical fault of circuit breakers is developing rapidly.

In [11], the coil current and time node values in the process of closing and closing of the high-voltage circuit breaker are taken as the feature quantity, and the fault diagnosis is realized by analyzing the gray correlation degree.

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The literature [12-14] applied a neural network to train the coil current signal. Among them, the literature [12] uses the convolutional neural network to train the current characteristic signal, avoiding the signal preprocessing process, and the training result has higher precision. Literature [13] is the fault state of the current signal is encoded and compares the training results of the BP neural network model, the normalized processing results of practical. Literature [14] uses probabilistic neural networks to process signals to avoid local convergence, and the diagnostic accuracy is higher than the BP algorithm.

3.2. Vibration Signal

The vibration signals of the high voltage circuit breaker is consists of a series of different time operating mechanism movement occurs when the impact of vibration waveform, the starting time of different vibration signals, amplitude, frequency, and other index represents the circuit breaker inside the basic information of the different parts of the vibration, therefore, vibration signal becomes the mechanical failure of high voltage circuit breaker mainly research today.

3.2.1 Wavelet packet

Wavelet packet decomposition can effectively solve the problem that only low-frequency signals are decomposed during the decomposition process, while high-frequency signals are not decomposed so that the frequency resolution decreases with the increase of frequency. Wavelet packet decomposition not only decomposing the low-frequency part, but also implementing the decomposition of the high-frequency part, and the wavelet packet decomposition can adaptively choose the corresponding frequency band to match the signal spectrum, which is a more fine decomposition method than wavelet decomposition.

Literature [9] reduces frequency band aliasing caused by wavelet function by increasing the vanishing moment in wavelet packet decomposition.

In literature [15], it is difficult to distinguish the fault of closing spring in wavelet packet decomposition by using cross-correlation delay time analysis. High discrimination accuracy is obtained.

Literature [16] can reduce the complexity of the wavelet packet algorithm by using a binary tree algorithm to implement wavelet packet decomposition.

3.2.2 Empirical Mode Decomposition

3.2.2.1 Empirical Mode Decomposition

Empirical Mode Decomposition (EMD) first proposed in 1998, is a method for processing nonstationary and nonlinear signals. EMD decomposes the changes at different scales of signal step by step to produce a series of eigenmode functions (IMF) with different characteristic scales. By decomposing the signal sequence into the sum of the intrinsic modal components and a residue in different frequency bands, the local features of the signal can be well highlighted.

In [17], the energy is calculated by the integral integration of the time axis of the IMF function after EMD decomposition and normalized, and its energy entropy is calculated as the feature quantity.

In literature [18], EMD is used to decompose the signal into components at the early stage, middle stage and late stage. Calculate the energy entropy of the equal time segment as the characteristic quantity. The accuracy of the EMD decomposition algorithm is improved.

Aiming at the problem of signal decomposition distortion easily generated by signal boundary during EMD decomposition, literature [19] improved the EMD decomposition algorithm by using the least square method, which can effectively alleviate the inherent endpoint effect of EMD.

In [20], by comparing the wavelet packet energy entropy and EMD energy entropy as the diagnostic accuracy of feature quantity, the combined wavelet packet decomposition, and EMD

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decomposition are proposed to extract the total energy vector of the IMF component as the feature quantity.

3.2.2.2 Ensemble empirical mode decomposition

In 2009, Huang proposed a signal processing method based on set empirical modal decomposition (EEMD), which is an optimization of the EMD method. The decomposition principle of EEMD is as follows: when white noise is evenly distributed throughout the time-frequency space, the time-frequency space is composed of different scale components divided into filter Banks. Signal areas of different scales are automatically mapped to appropriate scales associated with background white noise. Each test can produce very noisy results. When the noise is different in each independent test, the noise will be eliminated when the overall mean of sufficient tests is used. The mean of the population will eventually be considered the real result. As more and more tests are carried out, the added noise is eliminated, and the only durable part is the signal itself.

In [21], after the vibration signal is processed by EEMD, its sample entropy is extracted as the feature quantity.

In [22], EEMD and Hilbert-Huang transform (HHT) are jointly applied to two-dimensional data processing, and the vibration signal and sound signal are defined as one-dimensional sequence combination in the lower x, y-direction for processing. The principle of scale combining is used to obtain its energy entropy as the feature quantity.

In [23], the median filter is used to filter the residual function generated in the EEMD decomposition process, which can effectively remove the strong noise point and improve the accuracy of EEMD decomposition.

In [24], the energy entropy after EEMD decomposition is combined with its RMS value as the feature quantity, which is more adaptive than the wavelet packet decomposition. The RMS value as the metric value describing the signal amplitude can improve fault recognition accuracy.

3.2.3 Empirical wavelet transform

Empirical wavelet transform (EWT) is a multi-component signal decomposition method proposed in 2013. In this method, the Fourier spectrum of the original signal is segmented adaptively, and the orthogonal wavelet filter bank is constructed by using the corresponding wavelet filter in each segmented interval, and then the amplitude-frequency modulation components are extracted. EWT can avoid the shortcomings of EMD, which are easy to produce modal aliasing and false modal.

In [25], the traditional wavelet transform is used to define the empirical wavelet transform. It does not require multiple iterations of EMD decomposition. The decomposition yields fewer modalities and is less affected by modal aliasing, and is less prone to false modalities.

Literature [26] proposed that in the adaptive segmentation of EWT, the maximum value of amplitude was detected in the range of frequency domain and arranged according to the rule from large to small. The first n-1 maximum points were selected to select the appropriate algorithm to determine the boundary.

3.3. Sound Signal

Using a sound signal to diagnose the mechanical fault of high-voltage circuit breaker is a method proposed in recent years. The sound signal and vibration signal both come from the action of the circuit breaker mechanism, the difference lies in the different medium of transmission, but the sound signal is easily affected by environmental noise. Therefore, the sound signal is suitable for use as an auxiliary decision basis of the vibration signal.

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In [27], the K-S test method is used to extract the sound feature signal, and the Relief-F algorithm is selected for feature selection, which can reduce the calculation amount in the recognition process without ensuring the loss of important features.

In [23], the vibration signal is combined with the sound signal for fault diagnosis. The fast signal separation is performed by the fast kernel independent component analysis (Fast-KICA), and the two-dimensional spectral entropy of the vibration signal and the sound signal is extracted as the feature quantity.

4. FAULT IDENTIFICATION CLASSIFICATION

4.1. Support Vector Machine

Based on statistical learning theory and structural risk minimization principle, support vector machine (SVM) transforms nonlinear problems in low-dimensional space into linear problems in high-dimensional space through kernel function and shows many unique advantages in solving small sample, nonlinear and high-dimensional pattern recognition.

Literature [28] joint algorithm using the cuckoo algorithm and simulated annealing algorithm for least squares support vector machine was optimized, a chaotic cuckoo algorithm combining the cuckoo strong global search ability and simulated annealing algorithm is relatively optimal capacity, the standard cuckoo algorithm, and annealing algorithm can achieve better accuracy and a small amount of calculation.

In literature [29], the grid search method (GS) was used to optimize support vector machines, and the global optimization ability of GS algorithm in the context of big data was utilized to divide the original data set through the idea of k-cv, so as to avoid excessive fitting of data, and high identification accuracy could be obtained.

4.2. Neural Network

The artificial neural network has the initial ability of self-adaptation and self-organization. In the process of learning or training by changing the weight value to adapt to the requirements of the environment. The same network may have different functions due to different learning styles and contents. There are two ways of learning and training. One is supervised or supervised learning: classification or imitation based on a given sample standard; The second is unsupervised learning or non-supervised learning: if only the learning mode or some rules are stipulated, the specific learning content will vary with the environment of the system (i.e. the input signal), and the system can automatically find the environmental characteristics and regularity, which has better adaptability.

In [30], the neural network-integrated learning model is used to train fault recognition of circuit breaker faults and has achieved good results.

In Literature [31], particle swarm optimization (PSO) was used to optimize the radial basis function (RBF) neural network, the neural network model has better accuracy than before and high precision.

5. SUMMARY

Nowadays, most of the research on the mechanical failure of high-voltage circuit breakers are carried out in the laboratory environment. The corresponding research has not been done under actual operating conditions, and the specific research results need to be tested.

At present, the research on the mechanical fault of circuit breakers mainly focuses on the vibration signal and coil current signal generated during the switching operation. There are few studies on other signals such as sound signals and contact stroke signals. Moreover, there are many types of mechanical faults in circuit breakers, and the situation is complicated. It is

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difficult to find a more widely used fault diagnosis method. Therefore, the following problems have been raised for the study of mechanical faults of high voltage circuit breakers:

1There are many kinds of mechanical faults in circuit breakers, so it is necessary to improve the general classification basis for different faults.

2The fault diagnosis should not only occur in the circuit breaker opening and closing process, but the fault caused by mechanical loss without the circuit breaker operating should also be studied in the next step.

3With the development of diagnostic technology, how to study fast and accurate fault diagnosis algorithms are the next research direction.

4The power Internet of things is the main direction of power construction in the future. How to realize the network diagnosis of circuit breaker fault needs to be further studied.

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