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Online monitoring of high-voltage switchgear installation

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Abstract: The high-voltage distribution device is an important part of the power supply system which shoulders the dual tasks of control and protection. The function of the high-voltage distribution device is closely related to the safe operation of the power supply system. The condition monitoring of high-voltage distribution device can detect the specific parts of the fault in a timely and effective way which can improve the stability of the system. The mechanical vibration signal of circuit breaker body in mine high-voltage distribution device is a rich information carrier which contains a large number of device operating status information. Using modern information processing technology, the special parameters of mechanical faults are extracted from vibration signals, which have very important practical significance. Based on the analysis of the common mechanical faults in the high-voltage power distribution unit, a set of online vibration signal processing system with perfect function and reliable operation has been developed, which provides the technical guarantee for the reliable operation of the high-voltage power distribution unit.

1 Introduction

High-voltage circuit breaker is an important equipment in power system. In the primary equipment of power system, it is the large power equipment after the generator and transformer in terms of a single device, but in terms of quantity and the size of the investment in the power station equipment, it is higher than the generator and transformer [1–3]. High-voltage circuit breaker is the most complete electrical equipment. When the high-voltage circuit breaker is in normal operation, the switching operation is completed, and the equipment or line is connected into the circuit or out of operation which has the function of operation control [4–7]. When the equipment and the circuit are out of order, the fault can be quickly cut off, the automatic reclosing is realised, the trouble-free part is ensured to run normally, and the operation and protection function is realised. As the link between power generation and power consumption, the reliable operation of high-voltage circuit breaker is of great significance to ensure the safety of power grid [8].

A large number of domestic and international survey data show that mechanical fault is the main fault of high-voltage circuit breaker. The international power grid conference (CIGRE) has conducted two worldwide investigations into the reliability of high-voltage circuit breakers and their operating mechanisms [7]. The results show that: most of the circuit breaker faults (70% of the main faults and 86% of the secondary faults) are mechanical failures, mainly involving the operating mechanisms, monitoring devices, and auxiliary devices. Therefore, the mechanical state of high-voltage circuit breaker directly affects whether it can successfully accomplish the task of separation and cooperation [9]. Here, the hardware circuit of the system is designed for the vibration signal online-processing system. The experimental results show that the system design is reasonable, the hardware design is simple, and the performance is reliable.

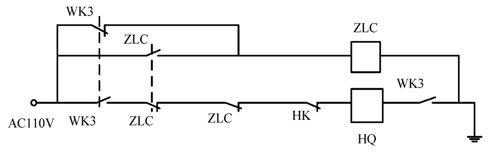

Fig. 1 *Closing electric circuit*

2 Fault analysis during operation of HV distribution equipment

The faults of HV distribution equipment occur frequently at the time of circuit breaker closing. Therefore, it is very important to study the failure of the power distribution unit, the fault of the switch, and the mechanism of the energy storage failure, and to do the correlation analysis and establish the sample data for the early warning system of the fault [10].

2.1 Switching fault

The breaker relies on the closing electromagnet to release the closing spring and the brake roller reliably locks the gate valve to complete a closing operation. Whether the storage of the closing spring can be released reliably and whether the lock valve can be locked reliably are the key to the success of the switch. There are two kinds of faults in circuit breaker closing: one is no closing action, mainly electrical fault; the other is the closing action, but it is separated from each other, mainly mechanical failure.

Causes of the first kind of situation: As shown in the picture 1, there are inching switch wk3 opening contact, closing contact for anti-jump relay ZLC, closing contact of auxiliary switch HK in the closing electrical circuit. The poor contact of these contacts will cause the coil voltage of the closing electromagnet HQ to be too low and the circuit breaker to be closed (Fig. 1).

The closing electromagnet can often be burned, fallen off, or jammed. The result will lead to no action of the closing mechanism. Failure of closing electromagnet occurs for the following possible reasons:

(i) Extended service of closing electromagnet and the influence of the surrounding environment (dust, high temperature, etc.) can easily cause the coil to be burnt out.
(ii) When the circuit breaker is in the switching operation, the fixed screws of the electromagnet are loosened or even dropped because of the violent vibration.

The causes of the second kind of situation: As the switch is not kept in the closing position, the breaker is separated immediately after the switch is switched on. There are several possibilities for this situation:

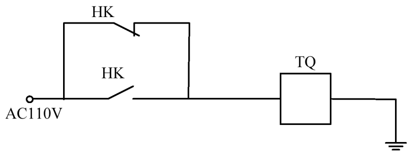

Fig. 2 *Gate circuit*

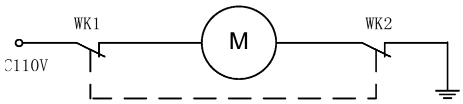

Fig. 3 *Energy storage electrical circuit*

(i) The brake engine and the brake roller surface wear serious, and the locking depth between the gates is reduced.
(ii) The brake roller is driven by the main shaft so that the gate is lifted. When the brake engine is falling, it is possible to cause the brake roller to lose support and cause the switch to fail.
(iii) The swing spring of the brake engine subassembly is tired or the axle is clamped.

Closing failure is a very serious fault, and must be found in time, otherwise it will cause serious consequences.

2.2 Break-brake fault

The circuit breaker depends on the switching electromagnet to release the switch, and the spring energy storage can complete the primary switching operation. The reliable release of the gate spring is the key to the successful switching. Similar to the closing phenomenon, the fault of circuit breaker switching can be divided into two kinds: one is the electrical circuit fault and the other is the mechanical component fault.

As shown in the picture 2, because the auxiliary switch is normally open and normally closed, the poor contact of the contact causes the voltage on the gate coil TQ to be too low, which results in rejection of circuit breakers (Fig. 2).

Possible causes of mechanical failure are:

(i) As of the friction between the gate valve and the brake roller, the separation between the two is difficult.
(ii) The wear of the brake engine and the brake roller surface is serious, and the locking depth between the brake roller and the gate engine is reduced.
(iii) Improper adjustment of the gate fan position, the locking depth between the brake roller and the gate fan is reduced.

2.3 Energy storage fault

Circuit breaker energy storage operation faults can be divided into two categories: One is that the energy storage motor does not operate, resulting in failure to save energy; the other is the energy storage motor, but the spring does not store energy.

There are two reasons for the first kind of situation:

(i) As shown in the picture 3, the normally closed contact WKl, WK2 which connect stored energy motor have poor contact. It causes the energy storage motor to be too low to operate.
(ii) The failure of the energy storage motor causes the motor to not work (Fig. 3)

The second category occurs for several reasons:

(i) The detent spring is tired, broken, and detached, resulting in failure of the stored energy spring.
(ii) The end of the pawl is badly worn.
(iii) The detent is slipping at the contact with the notch on the cam.

The above causes the motor to operate and the energy storage shaft rotates, but the springs are not stored. At the same time, the normally closed contacts are closed, causing the motor to remain in operation.

3 On line monitoring of high-voltage distribution equipment

We do test and debug for the state monitoring and fault warning of the high-voltage distribution equipment. The hardware monitoring device includes the accuracy of data extraction, hardware interference. The subprogram of fault warning software is combed, including the wavelet analysis of vibration signal, the rationality of node coefficient selection, and the real-time performance of the interface.

Spectrum analysis of vibration signals can be used to understand the distribution of vibration signals in all frequency bands. It provides a priori knowledge for wavelet packet decomposition and reconstruction of signals.

The energy of each frequency band after wavelet packet decomposition in normal and two fault cases is calculated, which can tell us the energy corresponding to each frequency band is greatly changed. In order to analyse and induce data more intuitively, the percentage of the total energy of each frequency band is decomposed by wavelet packet decomposition in the normal state of the circuit breaker and the two fault states. For the same type of circuit breaker, the eigenvectors of the wavelet packet characteristic frequency band have good repeatability in the same mechanical state. As the energy spectrum corresponding to each turn off is not exactly the same, the authors find that the percentage of energy in each frequency band is relatively stable in a certain area, and it is convenient to extract the characteristic quantity as the number of experiments increases.

Three sets of data are analysed that: For different periods and varying degrees of mechanical changes of circuit breakers, the energy of each frequency band of wavelet packet almost varies in different degrees. A band that reflects the most intense state's change, although concentrates in the high-frequency part. The frequency distribution is dispersed, and it is not centralised regularly in one frequency band. Therefore, the authors can choose only from the point of view of probability and statistics. In the frequency bands which are most sensitive to the energy change of the representative frequency band, the frequency of occurrence is larger in the 3, 4, 7 band. In the wavelet packet decomposition tree, the corresponding frequency ranges of the three bands are 1.875–2.5 KHz, 2.5–3.125 KHz, and 4.375–5 KHz. Two frequency bands are selected as the state feature vectors and the corresponding frequency is 1.875–3.125 KHz. At the same time, the three frequency bands can reflect the vibration process of the circuit breaker.

For any unknown vibration signal, the wavelet packet energy spectrum can be used to know which frequency band changes obviously and the magnitude of the quantised value. Then the fault category of high-voltage circuit breaker can be estimated to achieve the purpose of fault diagnosis and early warning. Therefore, the wavelet packet energy spectrum method is used to identify the characteristic frequency of the fault and quantify it intuitively, which is easy to implement on the computer.

4 Conclusion

This paper has done the experimental study for fault diagnosis of high-voltage vacuum circuit breaker to obtain knowledge, built the experimental circuit, obtained the measured vibration signal by some modern signal-processing methods (such as wavelet analysis technique etc.). A variety of useful data are used as the accumulated data of the fault diagnosis knowledge base, which lays the foundation for the research of expert system in the future.

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