Design of sound monitoring and fault diagnosis system for dry-type transformers

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Abstract: This paper focuses on several common fault phenomena and possible causes of dry-type transformer. MATLAB programming realizes the processing of acoustic signal. Through the encapsulation of GUI interface program and the processing and analysis of a large number of fault signals, fault sets are formed. Through the actual transformer fault acoustic signal processing, the main fault frequency of the acoustic signal is extracted and used as an important criterion for transformer fault detection.

1. Introduction

Power transformer is an important part of power system, which has the function of changing voltage, isolation and power distribution. Dry type transformer is one of the most used disaster prevention transformers. At present, the manufacturing technology is very mature, many companies at home and abroad can manufacture in batches, and the proportion of domestic dry-type transformer is increasing year by year [1]. Dry type transformer adapts to the environment of high pollution, high temperature and humidity. It has a series of advantages, including flame retardant, flame retardant, pollution-free and maintenance-free. However, once a fault occurs, it needs to be repaired for a long time, and the impact is relatively serious. If the fault can be found in time and solved quickly, the harm caused by transformer fault can be reduced or avoided to the greatest extent.

Some skilled old workers can judge the operation of the transformer by listening to the sound of the transformer, which is actually a primary application of audible technology. Transformer fault diagnosis methods mainly include vibration diagnosis, spectrum diagnosis, acoustic diagnosis, infrared and thermal imaging diagnosis, non-destructive monitoring and Ferrography Diagnosis [2]. Vibration detection method [3-5] does not affect the normal operation of power transformer, but the installation and maintenance is more troublesome. Audible technology has great advantages in on-line detection, microphone and other sound signal receiving device installation and maintenance is simple, sound signal acquisition and recording is also very fast and simple, compared with vibration detection, there is no need to paste sensor, cost saving, no electromagnetic signal in the whole process, no electrical contact with the equipment, will not affect the accuracy of detection.

The main content of this paper is to design a kind of human-computer interaction interface: Based on a large number of processing and extracting fault sounds, and extracting fault frequency in the designed program, reasoning and judgment are carried out. After recording the sound of dry-type transformer, you can choose to record it directly into the program or add program analysis after recording an audio file. Compared with the previous fault frequency, when the frequency is roughly similar, it can...
be determined as a fault.

2. Dry-type transformer audible sound technology

Audible technology is a kind of transformer fault diagnosis technology, which can analyze the noise in the frequency band from 20Hz to 20kHz and judge the operation of transformer \(^6\). The noise of dry-type transformer mainly comes from winding, iron core, box vibration and fan sound \(^7\).

Transformer faults can be generally divided into two categories: internal faults and external faults. Internal fault generally refers to the fault of transformer auxiliary equipment. External faults include damage caused by lightning strike, overvoltage caused by system misoperation, etc. The following are some common faults:

(1) The winding and insulation of transformer may have insulation aging, winding damp, winding turn to turn, high and low voltage windings between phases may have short circuit, open circuit and so on.

(2) Multi-point grounding of iron core may cause circulating current and overheating of iron core.

(3) The welding joint of high-voltage lead may be bad, and the lead clamp plate may collide with each other, resulting in the arc of lead joint burning.

(4) The low-voltage lead may be burnt out due to the discharge between the two-phase leads.

Many faults are closely related to sound. And there will be a lot of noise in case of failure.

(1) The dry-type transformer has noise. If the sound of the transformer is louder than usual and there is a disordered sound, it may be caused by the loosening of the internal clamp or the iron core and other individual parts, which increases the vibration amplitude of the silicon steel sheet.

(2) If the dry-type transformer has a similar boiling sound, the transformer winding may have a short circuit fault, or the tap changer may overheat due to poor contact.

(3) When starting large capacity power equipment or short circuit occurs in low-voltage circuit.

(4) When there is discontinuous and abnormal noise in dry-type transformer, it may be caused by poor contact in high-voltage cabinet.

(5) If the sound intensity of the transformer is very strong and accompanied by uneven popping sound, it may be the internal or surface insulation breakdown of the transformer.

(6) If partial discharge occurs inside or on the surface of the transformer, there will be "crackle" discharge sound in the sound.

The main causes of large power transformer failure are winding deformation, insulation pollution and core failure. Most of which are mechanical faults. Therefore, it is necessary and realizable to use audible technology to detect the operation state of transformer.

3. Realization of sound monitoring and fault diagnosis design

3.1. Modeling and Implementation

In this paper, the sound signal is further processed with the help of MATLAB software. In addition, MATLAB can not only realize various image processing, but also create a relatively simple human-computer interaction interface when recording and inputting audio files.
Figure 1. GUI human-computer interaction interface

Dry type transformer is in dynamic stability in actual operation, and the sound frequency is in a dynamic fluctuation. The sound contains all kinds of noise and sound of normal operation. Different characteristic frequencies indicate that dry-type transformers are in different operating conditions. The characteristic frequency of each operating state is approximately constant. Therefore, we can choose to judge the fault type by the characteristic frequency. Fast Fourier transform (FFT) is one of the important methods in signal processing. There are many FFT algorithms. According to whether there is exponential factor in the operation process, WN can be divided into two kinds of algorithms with and without exponential factor. Among these algorithms, radix-2 algorithm is most commonly used. In this paper, the complex FFT program of frequency dimension extraction based on radix-2 is written to realize the purpose of fast separating frequency and obtaining characteristic frequency.

The sampling frequency of general recording equipment is 32000Hz, 32000 sampling points are selected in FFT transformation, so that the frequency resolution is 1Hz, so that the sound signal within 1s can be analyzed. The time domain waveform of the speech signal, the frequency response diagram of the original speech signal and the FFT spectrum diagram of the original speech signal are drawn with MATLAB.

Figure 2. Examples of sound processing

3.2. Acquisition and preprocessing of acoustic signal

Noise and other interferences need to be removed in acoustic signal acquisition [8]. The working environment of transformer is a relatively complex situation. Now we need to extract a stable and noiseless transformer fault sound, and then separate the spectrum of transformer fault sound, and take the characteristic frequency as the judgment basis. This topic adopts two methods to collect transformer sound, one is to use a microphone, connect to the program, realize the program to judge the recorded sound and extract the characteristic frequency, the second is to use a recorder to record on site, and then enter the program. It is better to choose high fidelity as the recording equipment for the recording pen. Some researches have studied the electret condenser microphone, which shows that it can meet the
requirements of field acquisition [9].

3.3. Data processing
When the dry-type transformer works, ordinary people can't distinguish the running state of the transformer through their ears. Through the design of software, the sound frequency of the dry-type transformer can be displayed directly and clearly in front of people. Compared with experience, intuitive data is more reliable. Through the sampling comparison of several groups of experimental data, the sound information characteristics of multiple groups of transformers are obtained. More than 30 groups of data collected were compared and analyzed. The main frequency of transformer fault is shown in table 1:

| Experiment number | Characteristic frequency/Hz | likely failure | Experiment number | Characteristic frequency/Hz | likely failure |
|-------------------|-----------------------------|----------------|-------------------|-----------------------------|----------------|
| Fault1            | 300Hz max, 100Hz            | Core vibration | Fault11           | 100Hz max, 400Hz            | Partial Discharge |
| Fault2            | 100Hz max, 300Hz            | Core vibration | Fault12           | 250HZ max, 200Hz            | Corona discharge |
| Fault3            | 50Hz max 360Hz, 250Hz, 660Hz| Corona discharge | Fault13           | 300HZ max, 500Hz            | Core vibration |
| Fault4            | 100Hz max, 400Hz, 300Hz     | Partial Discharge | Fault14           | 300HZ max                   | Core vibration |
| Fault5            | 400Hz max, 100Hz            | Partial Discharge | Fault15           | 400Hz max                   | Core vibration |
| Fault6            | 100Hz max, 300Hz and 350Hz  | Core vibration | Fault16           | 300Hz max                   | Core vibration |
| Fault7            | 100Hz max, 400Hz            | Partial Discharge | Fault17           | 500Hz max, 300Hz, 200Hz     | Core vibration |
| Fault8            | 100Hz max, 200Hz            | Core vibration | Fault18           | 100Hz max                   | Core vibration |
| Fault9            | 100Hz max, 200Hz            | Core vibration | Fault19           | 400Hz max                   | Core vibration |
| Fault10           | 250Hz max, 100Hz            | Core vibration | Fault20           | 400Hz max, 350Hz            | Core vibration |

a. Corona discharge  

b. Partial discharge
According to the above theoretical analysis, the sound frequency of dry-type transformer is about 100Hz in normal operation, which is related to silicon steel sheet structure, winding vibration and box vibration. According to a large number of fault signal processing, we can find that the frequency of fault sound characteristics is mainly 100Hz, 200Hz, 300Hz and 600Hz, and there are few characteristic signals of 1000Hz or above. It is also consistent with the analysis of the transformer operating noise mainly with the magnetostriction of the core under excitation and the vibration of the winding under Lorentz force. According to the research, the main frequency of corona discharge is 250Hz, and in addition to 250Hz, there are 50Hz and its odd frequency components. The spark discharge frequency of dry-type transformer is mainly within 1000Hz, and the main frequency is about 100Hz, which shows the continuous spectrum of envelope line. All of these can be used as the basis for the fault diagnosis of transformer. In the actual operation process, it is possible to distinguish whether there is a fault by observing the spectrum diagram. We can get the following types of faults: when the fault sound of dry-type transformer is mainly 200Hz or other 100Hz multiple and has other characteristic signals with higher amplitude frequency, it can be judged as transformer core vibration; when the characteristic frequency of fault sound of dry-type transformer is 250Hz or 50Hz, corona discharge can be judged; When the fault sound of dry-type transformer is a characteristic signal with the frequency of 200Hz as the main and no other higher amplitude frequency, it can be judged as winding vibration; when the sound frequency of dry-type transformer fault is mainly 200Hz, there is no other characteristic signal with higher amplitude frequency and the amplitude of the main frequency is smaller, the judgment can be regarded as breakdown discharge; when the fault sound of dry-type transformer is mainly 400Hz and the basic frequency ratio of 100Hz is 100Hz When the signal is slightly lower, it can be judged that partial discharge occurs in the transformer.

4. Conclusion
In this paper, the fault diagnosis method of dry-type transformer based on audible technology is deeply studied. Based on the characteristic frequency data obtained by processing a large number of fault acoustic signals, this paper designs a system which can judge the operation state of transformer by analyzing the characteristic frequency of transformer sound. The research results of this paper can draw the following conclusions: there are many kinds of dry-type transformer faults, different identification methods, and each has its own advantages and disadvantages. Through theoretical analysis, it can be seen that the sound in the operation of transformer mainly comes from the magnetostrictive effect of the iron core under the excitation and the Lorentz force of the winding current in the magnetic field. The core vibration and winding vibration propagate to the box and then to the air through a complex process; through the processing of a large number of data, we can know that the characteristic frequency of transformer fault sound mostly appears in the multiple of 50 Hz, but rarely more than 1000 Hz high-frequency components, which is in line with the theoretical analysis. Generally, the sound frequency of corona discharge is about 250Hz, and that of spark discharge is about 100Hz.

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