Field Vibration Feature and Related Factors Analysis of 110kV Transformers

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Abstract. Transformer vibration is closely related with its operating condition. In order to realize transformer operation condition evaluation, vibrations of sixty-two 110kV transformers are tested. The acceleration amplitude, base frequency amplitude, base frequency ratio, dominant frequency amplitude, dominant frequency ratio and frequency complexity are chosen as vibration features. Statistical analysis of the feature distribution is conducted to determine the normal range of the vibration features. In addition, the influence of operating life on transformer vibration features is also analyzed. The result shows that for most transformers vibration acceleration amplitude, base frequency amplitude, base frequency ratio, dominant frequency amplitude, dominant frequency ratio and frequency complexity are in the range below 5.0m/s², 1.0m/s², 0.3, 2.0 m/s², 0.9 and 3.0, respectively. The vibration amplitude, base frequency and dominant frequency amplitude will increase obviously if transformer operating life is over 20 years. The analysis result will be used as data support for the operation condition assessment of transformers.

1. Introduction
Transformer body vibration is mainly produced by the joint action of iron core and winding vibration, through the core pads and transformer oil and other media to the surface of the box, causing the box vibration. The vibration characteristics of core and winding will be changed when the core and winding have mechanical defects like loose and deformation, which can cause the difference of the box surface vibration compared with normal condition. Therefore, the vibration detection of transformer box surface can be used for diagnose transformer internal structure defects [1-4].

Compared with frequency response method and short-circuit reactance method, vibration detection can find early potential hazard of transformer, and it does not affect the normal operation of the transformer and has no direct connection with the electrified system [5-7]. Hitherto, there are many reports about the research results of transformer vibration around the world, mainly concentrating on measurement method for transformer vibration, vibration signal and its characteristic analysis, and transformer status evaluation method based on vibration. However, because of the complicated and changeable operating conditions of transformers, the problems about transformer vibration features and its universality should be further researched.

In this paper, field vibration test is carried out on sixty-two 110kV transformer from different manufacturers. The transformer vibration features are calculated. The distribution analysis is conducted
to determine the feature range in normal condition. In addition, the influences of cooling type, operating life and manufacturers on the features are also analysed.

2. Transformer Vibration Test Method
According to existing research results, vibration measuring points are generally set at the bottom of the transformer oil tank, as shown in Figure 1. Three vibration measuring points are set in the high-voltage side of transformer during field test. The sampling frequency is 65536Hz and the sampling time is 10s.

![Vibration measurement point distribution](image)

**Figure 1.** Vibration measurement point distribution

3. Transformer Vibration Features
There are three features of transformer vibration. Basic frequency ratio is expressed as

\[ R_2 = \frac{A_2^2}{\sum_{i=2}^{20} A_i^2} \]  

where \( A_2 \) is basic frequency amplitude and \( A_i \) is the vibration amplitude at the \( i \)th harmonic frequency of 50Hz.

Dominant frequency ratio is expressed as

\[ R_m = \frac{A_m^2}{\sum_{i=2}^{20} A_i^2} \]  

Where \( A_m \) is the dominant frequency amplitude.

Spectral complexity is expressed as

\[ H = \left| \sum_{i=2}^{20} R_i \log_2 R_i \right| \]  

Where \( R_i \) is the ratio of vibration amplitude at the \( i \)th harmonic frequency of 50Hz.

4. Distribution Analysis of Transformer Vibration Features
The vibration test is carried out on sixty-two 110kV transformers in field operation. The cooling methods include natural cooling and forced air cooling. Because of the difference in the different position of transformer tank, and in order to improve the representativeness of the results of vibration test, the average value of the frequency spectrum of three vibration measuring points is used for represent the spectrum of transformer vibration. The features of basic frequency amplitude, basic frequency ratio, dominant frequency amplitude, dominant frequency ratio and frequency complexity are calculated.
4.1. Vibration Amplitude Distribution
The amplitude distribution of vibration acceleration of transformer is shown in Figure 2. It is observed that the amplitude distribution of vibration acceleration of 110kV transformer with different manufacturer and different capacities is mostly in the range of below 5.0 m/s², accounting for about 80.6% of total number of tested transformers. About 9.7% of transformer vibration acceleration is in the range of 5.0 m/s² to 10.0 m/s². The ratio of transformers with vibration acceleration amplitude exceeding 10.0 m/s² is about 8.1% of the tested transformers.

4.2. Basic Frequency Amplitude
The distribution of amplitude and basic frequency vibration ratio is shown in Figure 3. It can be seen that the vibration amplitude of the basic frequency is mainly in the range of 1.0 m/s², accounting for about 88.7% of the tested transformers. Only 7 transformers are found with the basic frequency amplitude exceeding 1.0 m/s².

4.3. Dominant Frequency Amplitude
The feature distribution of dominant-frequency amplitude is shown in Figure 4.
4.4. Frequency Complexity
As one of the key features, frequency complexity characterizes the dispersion degree of vibration frequencies. The feature distribution of frequency complexity is shown in Figure 5. And the vibration frequency distribution of this transformer is shown in Figure 6.

5. The Influence of Operation Time on Transformer Vibration Features
With the increase of operation time, the change of the amplitude of transformer vibration acceleration is shown in Figure 7 and the three fitting curves of the change process are also shown in the figure. In the same way, the relations between basic- and dominant-frequency amplitudes and the operation time are analyzed, as shown in Figure 8.

The variation relationship of basic- and dominant-frequency rate, frequency complexity and operation time of transformer are shown in Figure 9 and Figure 10, respectively.

![Figure 4. Dominant-frequency feature distribution](image)

![Figure 5. Frequency complexity distribution](image)
Figure 6. Vibration spectral distribution

Figure 7. Vibration amplitude versus operation time

Figure 8. Fundamental- and dominant-frequency vibration amplitude versus operation time
6. Conclusion
In this paper, vibration signals of 110kV field operating transformers from a large number of different manufacturers are tested, and the distributions of vibration amplitude, basic-frequency amplitude, basic frequency ratio, dominant-frequency amplitude, dominant frequency ratio, frequency complexity and the variations of the features with operation time are analyzed. The main conclusions are as follows.

1) More than 80% transformers have the vibration acceleration amplitude within the range of 5.0 m/s², and the number of transformers with vibration acceleration amplitude over 10 m/s² is small.

2) The basic-frequency amplitude of most transformers is basically in the range of 1.0 m/s² and basic frequency ratio is in the range of 0.3. The vibration energy of field operating transformer is more concentrated on high harmonic frequencies.

3) The vibration amplitude of dominant frequency from different transformers generally uniformly distributed in the range of 2.0 m/s².

4) The spectral complexity is mostly distributed in the range of 1.5 to 3.0. Only a few transformers have the spectral complexity over 3.0. Thus, it is suggested to strengthen vibration monitoring of this kind of transformers.

5) The transformer operation time has a large influence on its vibration amplitude, basic- and dominant-frequency amplitude. For transformers with operation time over 20 years, the vibration features referred above is obviously increased, but the operation time have no significant influence on basic- and dominant-frequency ratios and spectral complexity.
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