Test and Experimental Study on Vibration and Noise Characteristics of Distribution Transformer

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Abstract. With the continuous scale expansion of power grid, more and more distribution transformers go deep into the urban residential center, which results in increasingly prominent vibration and noise problems. Mastery of the vibration and noise characteristics of the distribution transformer and its propagation law is an important test basis for proposing vibration and noise reduction measures. Relying on a typical 10 kV distribution transformer, vibration and noise tests were carried out on the interior and exterior of transformer tank respectively in this paper. Advanced fiber-optic hydrophone test system was adopted in the test to solve the problem of accurately measuring the internal sound pressure of the transformer in a high electromagnetic field. Finally, time-domain analysis and frequency-domain analysis were done on test data to acquire the acoustic-vibration characteristic and propagation law of the 10 kV distribution transformer. The vibration spectrum of a transformer body is mainly 100 Hz and its rate, the vibration characteristics of distribution transformer tank is basically consistent with the internal transformer core, and the propagation of transformer vibration and noise in oil shows obvious laws.

1. Introduction

With the power grid construction and urbanization progress of China, substations are closer and closer to urban residents, so the vibration and noise generated by transformers cause widespread concern among people. Distribution transformers belong to power grid terminal stations and are in large quantity. Up to 60% refers to high-energy consumption and low-end distribution transformers, showing serious noise pollution. Average sound pressure level of distribution transformers is mainly 50 dB(A)~70 dB(A). Especially distribution transformers in residential areas impose great influence on surrounding residents at night or in electricity consumption peak in summer due to the short distance from residential buildings. In some areas, up to 40 cases of disputes or complaints arising from noise of distribution transformers occur every year. In order to improve the noise environment of the distribution network, internal and external vibration and noise tests were done on transformer tanks based on typical 10 kV distribution transformer, to master the vibration and noise characteristics of distribution transformer and its distribution law, thus providing reliable test data reference for optimizing equipment parameter performance.
2. Test Methods for Vibration Noise of Distribution Transformer

In order to master the acoustic vibration characteristics of the distribution transformer, based on the typical 10kV distribution transformer, the coordinated vibration and noise test was carried out under no-load voltage and short-circuit current conditions, aiming to obtain the vibration and noise characteristics of the core, insulating oil and oil tank of the 10kV distribution transformer. The magnetostriction of the transformer core is the main noise source. The iron core has an irregular, stair-stepping staggered surface, with the staggering distance of 2cm -3cm generally. It is difficult to mount a vibration acceleration sensor on such a small section, and is easily disturbed from electromagnetic field when applying piezoelectric accelerometers. A fiber optical accelerometer is thus used for testing the vibration of the transformer core, as shown in Fig. 1. The fiber optical accelerometer is fixed with the upper and lower clamps of iron core; the vibration in three directions of the iron core is directly transferred to the clamps, and by testing the vibration of the clamps, the vibration test results of iron core can be obtained. The sound pressure in the insulating oil of transformers is tested with a fiber-optic hydrophone, and the sound pressure characteristics inside the insulating oil can be obtained with a fiber optical interrogator, as shown in Fig. 2. The conventional piezoelectric vibration sensor is used for testing the vibration of the tank of 10 kV distribution transformer.

3. Arrangement of Test Point

3.1. Test point for vibration of iron core

The fiber optical accelerometer is mounted on the iron core of a 10kV400KVA distribution transformer, and the structure of the distribution iron core is shown in Fig.3. It is mounted on the clamp on both sides of the iron core; two test points are set at the end and in the middle on the upper clamp and are used to test the vibration in X, Y, Z directions respectively, one test point is set up in the middle on the clamp and is used to test the vibration in X, Y, Z directions, and a total of nine sensors are set up. The fiber optical accelerometer is connected to an acquisition instrument via an oil level gauge. The layout plan of test points is shown in Fig. 3 and Fig. 4.
3.2. Test point for sound pressure in oil
The tank of a 10 kV distribution transformer is small, resulting in very limited space available for hydrophones. Upon negotiation with the transformer manufacturer, only 2 hydrophones can be arranged symmetrically on both sides in the oil at upper section of the tank for test points for sound pressure in oil, as shown in Fig. 5 and Fig. 6. The fiber-optic hydrophones are connected via the oil level gauge.

Fig.5 Layout Plan of Test Points in Oil
Fig.6 Mounting of Hydrophone Test Points in Oil

3.3. Test points for vibration of tank
The traditional piezoelectric accelerometer is used for testing the vibration on surface of the transformer tank; it is arranged around the wallboard of the tank structure. The detailed test points are shown in Fig. 7 and Fig. 8 below.

Fig.7 LP Side of Test Points for Vibration of tank
Fig.8 HP Side of Test Points for Vibration of tank

4. Analysis of Test Results

4.1. Vibration of iron core
A total of 9 sensors are provided for testing the vibration acceleration of iron core, including C2, C1 and C3 in the X, Y and Z directions respectively for the test points of side pillar of upper clamp, C6, C5 and C7 in the X, Y and Z directions for the test points of central pillar of upper clamp, and C8, C4 and C9 in the X, Y and Z directions for the test points of central pillar of lower clamp. Some of the test results are as follows:
According to Figs.9-12, the maximum vibration amplitude of iron core is 0.15 m/s$^2$, and the main vibration frequency of iron core is 100 Hz and its frequency multiplication. It is mainly the winding vibration frequency of 100 Hz in short-circuit current state. The high frequency component for iron core vibration increases gradually in the no-load voltage state.

4.2. Sound pressure in oil

The hydrophones (S1 and S2) are totally provided for sound pressure in oil to record the vibration in insulating oil. The test results for S2 sound pressure in oil are as follows:
According to the figure above, the sound pressure in oil is relatively steady. The peak vibration level is 90 dB, and the sound pressure spectrum is mainly 100 Hz frequency multiplication. It is mainly the 100 Hz spectrum in short-circuit current state, and the high frequency component for sound pressure increases gradually in the no-load voltage state.

4.3. Vibration of tank
A total of 20 sensors are arranged on all surfaces of the tank to test the vibration acceleration of the transformer tank. Some of the test results are as follows:
According to the figure above, the vibration acceleration frequency of transformer tank is mainly 100 Hz and its frequency multiplication, and is 100 Hz in the current state; the high frequency component increases gradually in the voltage state, which is consistent with the vibration rules of internal iron core.

5. Conclusion
In this paper, a 10 kV distribution transformer is used as the test object for transformer acoustic-vibration coordination test. Advanced fiber-optic hydrophone test system was adopted in the test to solve the problem of accurately measuring the internal sound pressure of the transformer in a high electromagnetic field. Finally, time-domain analysis and frequency-domain analysis were done on test data to acquire the acoustic-vibration characteristic and propagation law of the 10 kV distribution transformers. The vibration frequency of transformer core, insulating oil and tank body is mainly 100 Hz and its frequency multiplication. It is mainly 100 Hz under short-circuit current state. When no-load voltage is applied, the frequency multiplication component of high frequency increases, and the nonlinear vibration of core gradually appears with the increase of voltage on the surface. The transmission frequency of vibration is consistent from inside to outside.
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