NON-ELECTRIC MEASUREMENTS-BASED ON-LINE DIAGNOSIS METHOD FOR THE FAULT OF TRANSFORMER WINDINGS

Yuying Shao, Hong Guan, Yu Zhang — Institute of Technology and Management, SMEPC –China
Zhijian Jin — Shanghai Jiao Tong University – China
shaoyy@etc.sh.sgcc.com.cn guanh@sh.sgcc.com.cn zhangyu@sh.sgcc.com.cn zjjin@sjtu.edu.cn

ABSTRACT

Transformers are the critical equipments in the power system. The online diagnosis of transformers is one of the most important measures to prevent the accidents. This paper proposes an online diagnosis method to detect the winding's deformation based on the vibration severity method. To validate the effectiveness of this method, we design a set of on-line signal acquisition device and a series of destructive experiments. Experimental results show that the proposed method is more sensitive than short circuit reactance method when detecting the winding fault caused by the shock of short circuit currents.

1. INTRODUCTION

Winding deformation of transformer is one of common faults. It would lead to winding's structural instability and reduce the transformer's ability to withstand short circuit, which causes transformer sudden damage accidents and results in heavy losses. Therefore, it is vital to monitor transformer winding condition on a real-time basis so as to prevent the sudden breakdown of the transformer. The main methods for detecting winding deformation are usually off-line, including short-circuit reactance method and frequency response method (FRA). There is not an appropriate online monitoring method to meet actual needs.

The changes of transformer winding states lead to the change of its vibration response. The winding vibration signals can be transferred to the transformer tank through structural parts and insulating oil. These signals can be gathered by attaching the vibration accelerometer on the transformer tank, which can be used detect the state of windings. The vibration signal gathering system does not directly connect with electrical system. Therefore, the diagnosis method based on transformer vibration is easy to detect the transformer state on a real-time basis, with good anti-interference performance.

2. DIAGNOSIS METHOD

2.1 Diagnosis mechanism

Using vibration diagnosis method to monitor transformer state is one of the hot topics in the past ten years [1-7]. It is found that with the transformer state being worse, the spectrum component of transformer vibration signals has a significant change. Canadian scholars presented a method to online detect the transformer state with the phenomenon [8].

Because of the nonlinear property of insulating cardboard material, transformer vibration spectrum changes with transformer's operation condition. When winding is excited by the current, winding vibration signal includes more harmonic components. If it is in normal states, the winding's mechanical strength will be high. The vibration response does not significantly change under the same exciting current. But the looseness or deformation of winding essentially affects the mechanical characteristics, which changes winding stiffness and makes the winding's nature frequency shift. Therefore, not only the response amplitude of 100Hz is changed, but also the amplitude of harmonic amplitude has an obvious change.

2.2 Vibration intensity method

According to above mechanism, the change of vibration response can be used to monitor the state of winding. Therefore, a new method based on vibration intensity is proposed to detect transformer condition. Vibration intensity can show the vibration level of transformer, as shown in equal (1) and (2) [9]:

$$a_{rms} = \sqrt{\frac{1}{n}(\sum_{i=1}^{n} a_i^2)} \qquad (1)$$

$$a_{id} = \sqrt{(\frac{\sum_{i=1}^{k} a_{Xrms_i}}{k})^2 + (\frac{\sum_{i=1}^{m} a_{Yrms_i}}{m})^2 + (\frac{\sum_{i=1}^{n} a_{Zrms_i}}{n})^2} \qquad (2)$$

Where,

a_i: the acceleration amplitude of spectrum at frequency i

a_{rms}: acceleration vibration level of measuring point

$a_{Xrms_i}, a_{Yrms_i}, a_{Zrms_i}$: the vibration level of measuring point i in the direction of *x, y, z*

k、m、n: the number of measuring points in the direction of *x, y, z*

The vibration intensity method gathers the vibration signal on the transformer tank, which is easy to detect the winding states on-line. At the same time, transformer vibration comprises core vibration and winding vibration [6]. The former is proportional to the square of voltage, while the latter is proportional to the square of current. When the vibration intensity method is used, it needs the same voltage and current to be computed.

3. THE STUDY OF TRANSFORMER DESTRUCTIVE TESTING

3.1 Test system and equipment

In order to verify its validity, the online monitoring method is first applied in the transformer short-circuit test. On one hand, the short-circuit shock test accelerates the process of transformer damage, which actually simulates the transformer short-circuit accident. On the other hand, the current and voltage in the test are kept nearly constant, which is the enough condition for using the method.

When transformer is carried out the short-circuit shock test, the transformer online vibration signal gathering system collects the vibration signal, which is controlled by signal gathering controller. According to the change of the vibration intensity, the gathering system diagnoses whether the transformer is working normally.

As shown in Fig. 1, the online vibration signal gathering system consists of accelerometer, online dynamic signal recorder (as shown in Fig.2), online signal gathering controller and signal test analysis software.

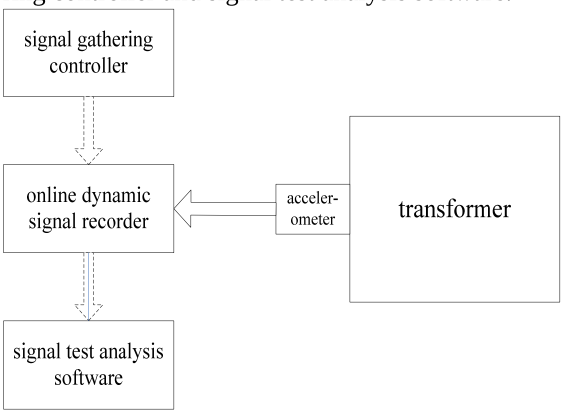


Fig.1 Diagram of online vibration signal gathering system

Fig.2 Online dynamic signal recorder

3.2 Destructive test

Transformer short circuit shock tests have been conducted according to the standard of GB 1094.5-85 or IEC 76-5:1976. To begin with, the low-voltage side of the transformer is short-circuited. Then the short-circuit shock occurs for different phase of windings in high-voltage side. The reactance of every winding is measured after every shock in order to detect the transformer winding state. Online gathering system uses real-time collected vibration signals to compute the vibration intensity and then detects the winding state by comparison with historical data.

In order to validate the method, short-circuit shock experiment was conducted on a transformer (rated capacity: 1250kVA; rated current: 72.17/1804A). Phase B winding separately suffered many short-circuit shock under short-circuit current of 584A、715A、883A、1019A、1130A、1256A and 1325A.The detailed measuring points are as shown in Fig.3.

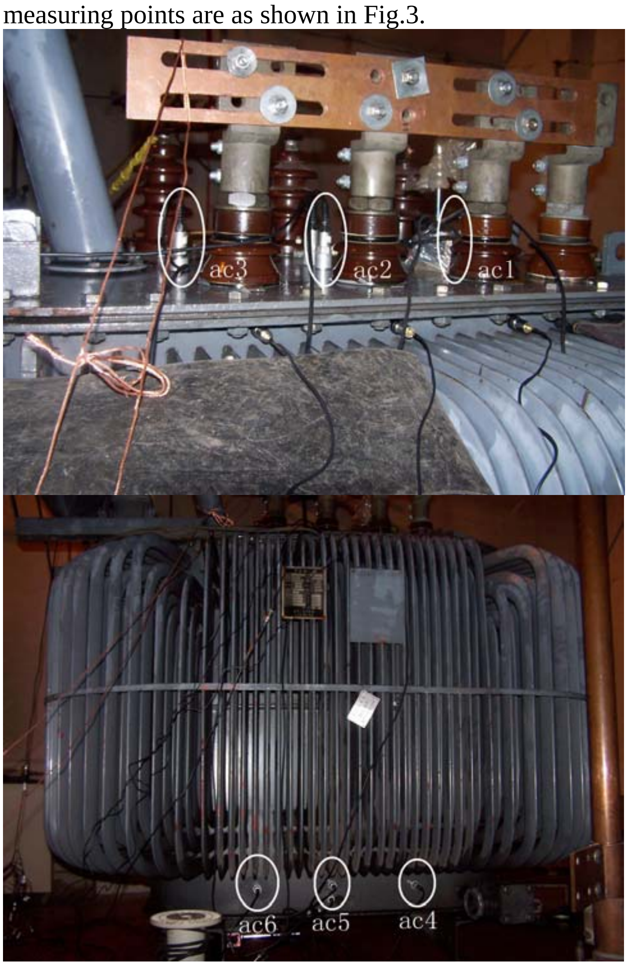


Fig.3 Locations of measuring points

Fig. 4 and Table 1 compare the vibration intensity of phase B under different short-circuit currents. It can be concluded that the vibration intensity increased by 6.59% during 8th shock, meanwhile, there is nearly no reactance change before and after the shock, i.e., still less than 0.1%. However, during 17th shock, the vibration intensity decreased by 10.7%, and the change of reactance is 0.31%. From 18th to 20th short-circuit shock, the vibration intensity changed obviously. For example, the vibration intensity increased by 18.29% during 20th shock, however, the reactance change is only 0.63%.

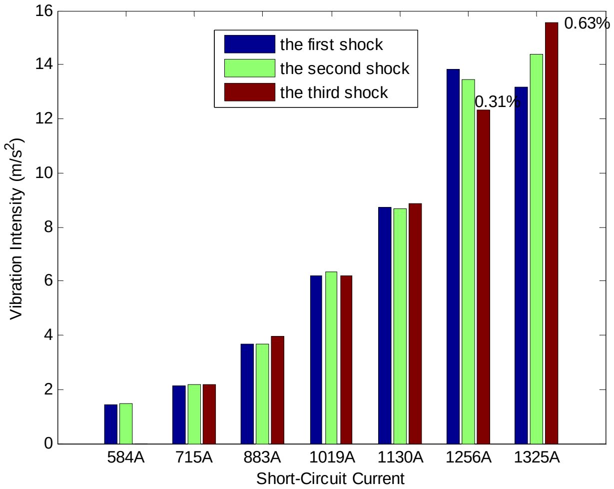
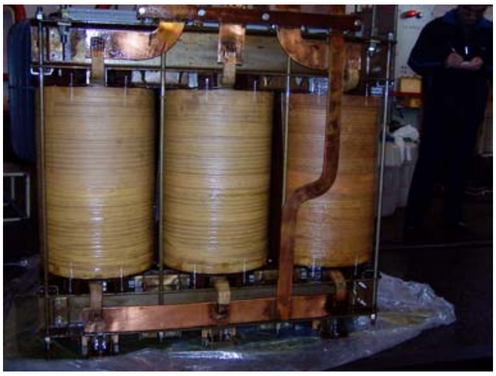


Fig.4 Vibration intensity comparison for phase B under different short-circuit currents

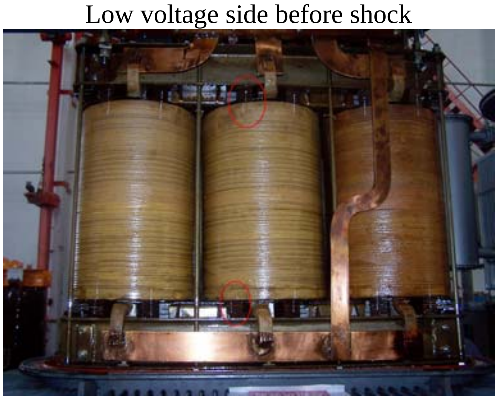
Table.1 Vibration intensity and reactance comparison

No.	Effective value of currency(A)	Vibration intensity (m/s^2)	Neighbor intensity change (%)	Reactance change (%)
1	583	1.44		<0.1
2	584	1.46	1.31	<0.1
3	714	2.12		<0.1
4	715	2.16	1.94	<0.1
5	715	2.17	2.05	<0.1
6	882	3.69		<0.1
7	883	3.66	-0.78	<0.1
8	883	3.93	6.59	<0.1
9	1020	6.22		<0.1
10	1018	6.32	1.65	<0.1
11	1019	6.22	0.05	<0.1
12	1130	8.74		<0.1
13	1130	8.70	-0.46	<0.1
14	1130	8.88	1.54	<0.1
15	1256	13.82		<0.1
16	1256	13.47	-2.52	<0.1
17	1258	12.34	-10.70	0.31
18	1325	13.16		\
19	1325	14.39	9.31	\
20	1325	15.57	18.29	0.63

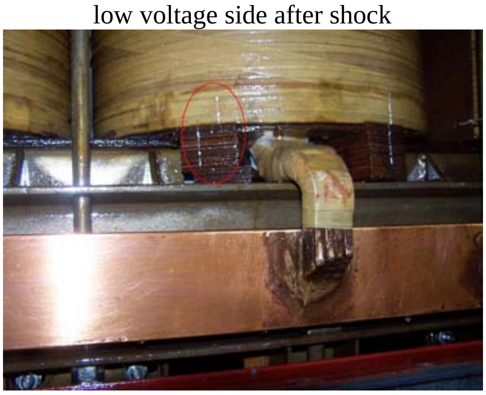
According to the regulation of GB1094.5—2003, the reactance change of 0.63% shows that the transformer is in the normal state. However, there are obvious changes in vibration intensity, which shows that the winding state was deteriorated. The conclusions from both methods are different. In order to know which is right, the transformer was dismantled. As shown in Fig. 5, phase B winding had obvious twist deformation.



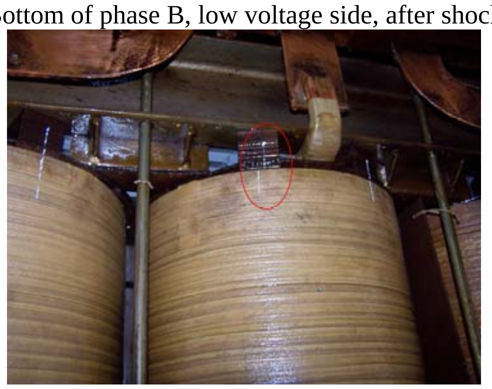
Low voltage side before shock



low voltage side after shock



Bottom of phase B, low voltage side, after shock



Top of phase B, low voltage side, after shock

Fig.5 Winding comparison before and after short-circuit tests

Therefore, compared to offline reactance method, the vibration intensity method can not only be used for the online detection of transformer states, but be more sensitive to show the change of winding states.

4. CONCLUSION

The deformation of windings is caused by the short-circuit impulse, which is one of the major faults for the transformer. To detect the winding's fault on a real-time basis, the paper proposes an online diagnosis method which compares vibration intensity under the same currents and voltage. A set of on-line signal acquisition device and experiments are designed to validate the effectiveness of the method. The experiments show that:

1) The vibration intensity is more sensitive and efficient than off-line reactance method;

2) The vibration intensity can be used as an effective online detection method for monitoring the winding's states.

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