Study on Electrically Excited Winding Vibration Frequency Response Under Various Clamping Pressures

Qiang Liu[1], Cao Zhan[2], Liang Lv[2], Linzi Zheng[2], Yuhang Shi[2]

1. Center of Equipment Status Evaluation Shaanxi Electric Power Research Institute of State Grid, Xi'an, China

2.State Key Lab of Electrical Insulation and Power Equipment, Xi'an Jiaotong University, Xi'an, China

I. INTRODUCTION

- Power transformer is one of the most crucial equipment in power system. Many references reveal that power transformer winding mechanical faults are mainly due to short circuit fault. Huge short circuit current which will be excited during short circuit impact can induce large electromagnetic force on the winding and cause winding radial and axial deformation. After many times of sudden short circuit, winding structure will be changed due to accumulative effect, which will reduce the lifetime of power transformer. Thus, transformer winding mechanical condition monitor and fault diagnosis is very meaningful in maintaining the safe and reliable operation of power transformer and even the whole power system.
- Modern winding deformation monitoring and diagnostic methods are always classified into off-line methods and on-line methods. Since transformer main structure is closely related to its frequency response characteristics, vibration frequency response can be used to study winding and core modal analysis and diagnose winding mechanical fault. Fenghua wang proposed using vibration sweep frequency response which ranges from 230Hz to 620Hz to diagnoses winding deformation. Through short circuit experimentation in a 220kV transformer with the preset deformation, it's found that correlation coefficient between frequency response curves is more sensitive to winding deformation than FRA method.
- This paper proposes to study the vibration frequency response characteristics of a winding model in a wider frequency band. The frequency band of vibration response can be 1000Hz. Furthermore, a special device is also installed on the top of the winding to adjust and measure the clamping pressure. Electrically excited vibration frequency response characteristics of the winding is studied under different clamping pressures. The correlation coefficient of different VFRFs are brought up as indicator to evaluate winding looseness degree.

II. EXPERIMENTATION AND DISCUSSION

A. Experimetation Method

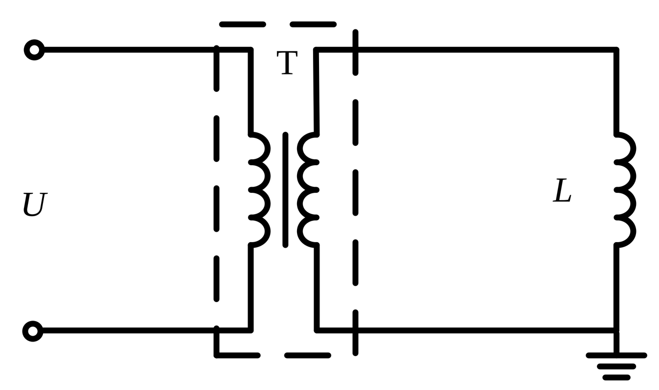


Fig.1 Test circuit diagram

(a) Harmonic source (b) Intermediate-frequency transformer

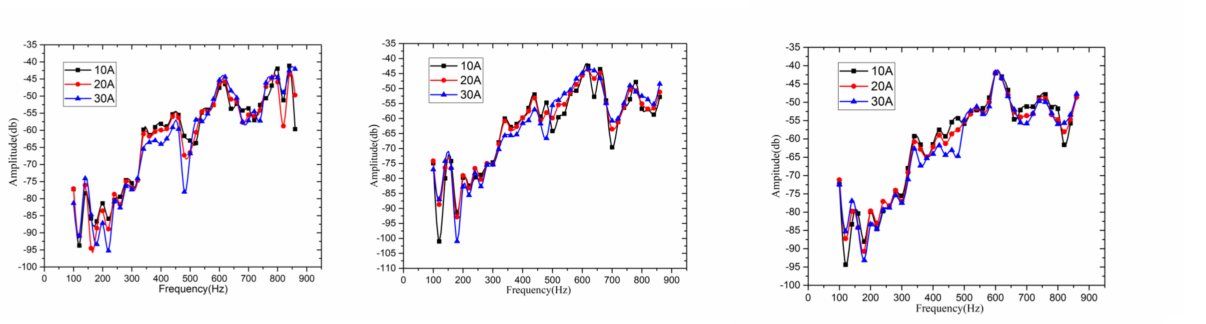
Fig.2 Test equipments

- The experiment platform consists of a harmonic source which rectifies the 50Hz current into other frequency, an intermediate-frequency transformer, a winding model and the control system. The test circuit is shown in Fig. 1. U represents the harmonic source, T is the intermediate-frequency transformer and L represents the single winding. The physical pictures of the harmonic source and the intermediate-frequency transformer are shown in Fig. 2.
- Fig. 3 shows the winding model. The structure in red frame is the change and measure part of clamping pressure. The black frame contains seven vibration measure locations.

Fig.3 Winding

B. Experimetation Results

In order to study the influence of different magnitudes of electromagnetic force on the winding structure, excitation current is changed from 10A to 30A, but winding clamping pressure remain the same. Fig. 4 shows that winding VFRFs are similar under different excitation currents.



(a) Clamping pressure 2.5Mp (b) Clamping pressure 3.0Mp (c) Clamping pressure 3.5Mp

Fig.4 VFRFs under different currents

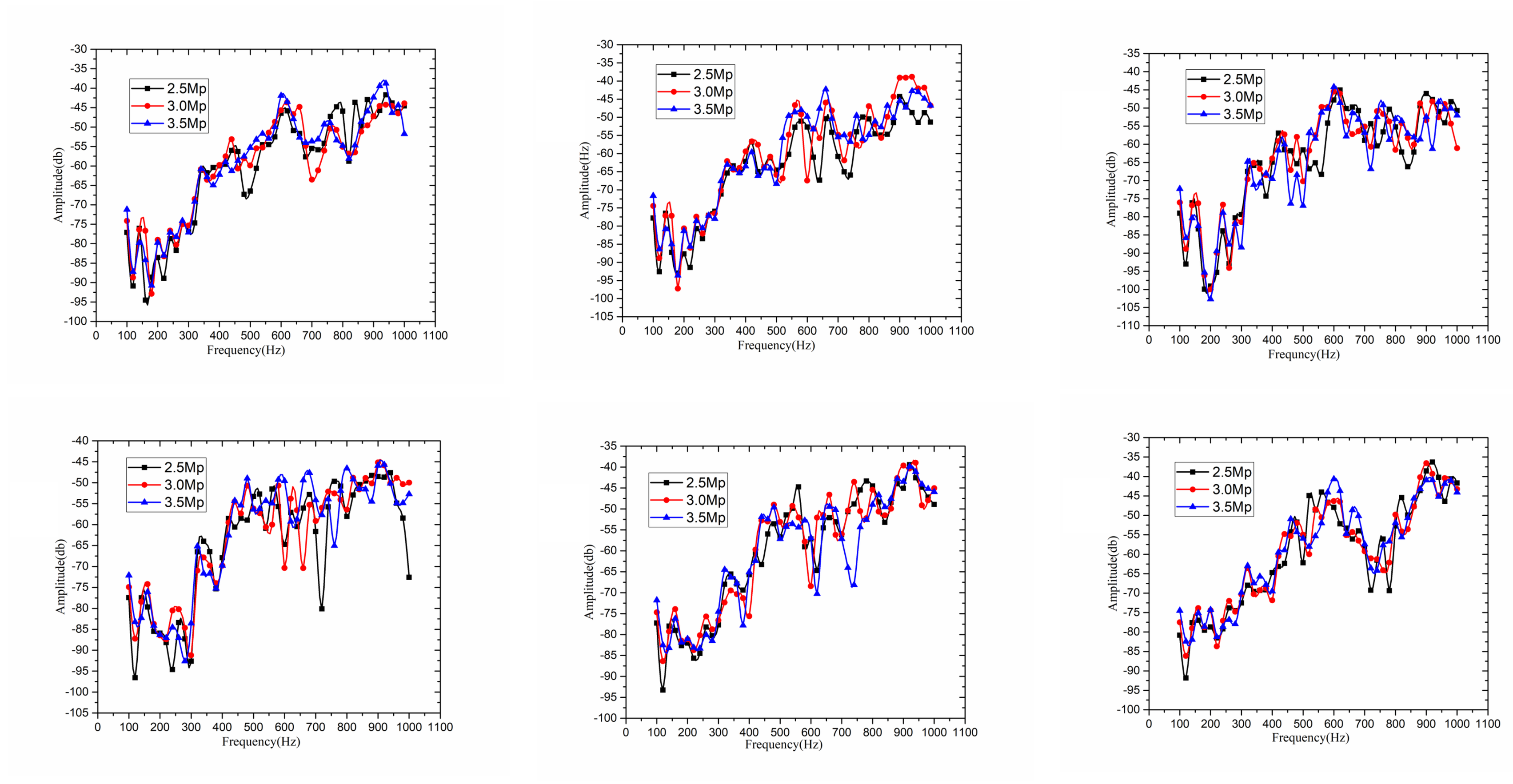


Fig.5 VFRFs under different clamping pressure

Only when the amplitude of excitation current is 20A is the effect of various clamping pressures studied next. Fig. 5 shows winding VFRFs under various clamping pressures. From (a) to (g) is the result of measure point 1 to measure point 7, which is arranged on the winding disc from the top to the bottom. It's found that

1) natural frequency under various clamping pressures changes apparently. For example, the first order natural frequency is 140Hz, 145Hz, 142Hz under clamping pressure 2.5Mp, 3.0Mp, 3.5Mp respectively. However, different order natural frequencies have no unified variation tendency at each measuring point. The reason may be that the modal numbers of this winding structure are too many, so modal aliasing effect is very obvious, then it's hard to obtain the correct natural frequency.
2) VFRFs amplitude increase gradually overall with the frequency increasing. In other words, the winding vibrates more intensively at high frequency range. According to the winding vibration mechnism, the amplitude of VFRF is corresponidng to excitation current frequency and increases with the square of current frequency.s
3) With the clamping pressure increasing, VFRFs are close to each other and show no clear seperation. The interval of preset clamping pressures is 0.5Mp which may be small compared with the winding structure clamping pressure, then cause the structure changes a little. However, the difference between the VFRFs still occures at some location especially in higher frequency range, so the variation of VFRFs can be utilized to evaluate the change of clamping pressure.

TABLE I. CC AT VARIOUS MEASURE POINTS

Current	10A		20A		30A	
CC	R_{01}	R_{02}	R_{01}	R_{02}	R_{01}	R_{02}
#1	0.479	0.441	0.713	0.642	0.572	0.562
#2	0.975	0.681	0.952	0.671	0.499	0.580
#3	0.600	0.525	0.583	0.489	0.651	0.605
#4	0.522	0.396	0.631	0.462	0.675	0.430
#5	0.600	0.564	0.773	0.810	0.665	0.619
#6	0.724	0.544	0.895	0.726	0.650	0.596
#7	0.342	0.754	0.609	0.929	0.600	0.774

III. CONCLUSION

Electrically excited winding axial vibration response is measured in the vibration frequency response experiment. The mechanism of winding structure frequency response is explained in detail. There are some important results: 1) Winding VFRF can be calculated by the division of vibration response and the square of excitation current. 2) Winding VFRFs are similar under various excitation amplitude which verifies the winding structure can be regarded as linear system approximately. 3) Winding VFRFs under various clamping pressures are different and CC is brought up to evaluate the variation. CC decreases with the clamping pressure variation increasing. 4) Measure location has a large influence on the sensitivity of CC when it is used as an indicator to evaluate winding looseness degree. This method is meaningful and need to be studied further.

Author email: 63451449@qq.com &zhancao@stu.xjtu.edu.cn