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The Excitation Performance Analysis of Transformer Made by Different Core Material Under DC Magnetic Bias

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Abstract:

The DC magnetic bias can affect the normal production and operation of the transformer. In this paper, by means of the finite element simulation software to simulate the excitation current fluctuations phenomenon of the three-phase transformer after adding DC magnetic bias, and by comparing the excitation current fluctuations of transformer made by different grades of electrical steel materials to analysis the influence factors of electrical steel materials on DC magnetic bias of transformer.

Key words: DC magnetic bias；excitation current; Transformer；Electrical steel

0、Introduction

DC magnetic bias phenomenon is that there is a DC current through the neutral point into the transformer windings, so that the transformer is not in a normal state. the working point of the transformer would be shifted under DC magnetic bias magnetization, the core rapidly access to the saturated state, seriously affect the normal work of the transformer, and excitation current amplitude increases rapidly, waveform distortion, harmonic content increase; transformer noise increases, vibration intensified; transformer flux leakage increase, the loss increase and temperature rise, lead to local overheating phenomenon of metal structure. Therefore, the transformer DC magnetic bias phenomenon cannot be ignored[1].

Based on the physical mechanism of DC magnetic bias, this paper studies the waveform distortion of the excitation current under DC magnetic bias combining the characteristics of electrical steel.

1、The reason for transformer DC magnetic bias and its effects

1.1 The reason for transformer DC magnetic bias

Online operation of the transformer windings have a larger DC magnetic bias, which can be caused by the following reasons:

(1) the dynamic change of the solar plasma wind and geomagnetic field interaction".

(2) the voltage and current curve in the alternative power system, or there is parallel operation between the DC transmission line and the AC transmission line.

(3) urban rail transit. The subway, rail transportation and some small mines train in big cities mostly adopts DC drive vehicles, the DC power supply rail transportation with the earth as one pole, similar to HVDC monopole operation, cause DC magnetic bias to the transformer above 110KV of the city. Its value is relatively small, frequent fluctuations; Its duration synchronize with the operation time of city railway[2].

1.2 The effects of DC magnetic bias to transformer

When the transformer winding flows through the DC current, especially the DC current flowing over the tolerance level, it will have a certain impact on the operation of the transformer, and the specific performance are as the following aspects:

(1) the transformer loss increases, the temperature increases, causes the local overheating; (2) the noise increases; (3) the vibration intensifies.

The above phenomenon is the most intuitive aspect of the influence of DC magnetic bias on transformer characteristics. DC magnetic bias causes transformer iron core saturation, loss and temperature rise, and thus cause transformer insulation aging; On the other hand, work reliability and life expectancy reduction although is not intuitive, but there is a potential risk[3].

When there is DC current as a part of the current of transformer, the DC flux and AC magnetic flux are added with each other and the bias flux is becoming a partial of total magnetic flux. The total magnetic flux is increased in positive half cycle and the negative half cycle is reduced, and the corresponding excitation current is also distorted. The solid line in Figure 1.1 is the magnetic characteristic curve without DC component, the dotted line is the magnetic characteristic curve with DC component. φ-I curve uses the broken lines OA and AB at both ends to represent the magnetization properties of the core, the OA segment is the unsaturated part of the magnetization curve, the slope is K_{OA}; the AB segment is the saturated part of the magnetization curve, the slope is K_{AB}, I_0 is the added DC, φ_0 is the corresponding DC magnetic flux. φ_N is the maximum value in the linear part of magnetic characteristic curve, I_N is maximum magnetizing current in the linear part. φ_n is magnetic flux of transformer without DC, I_n is the peak value of the corresponding excitation current [4].

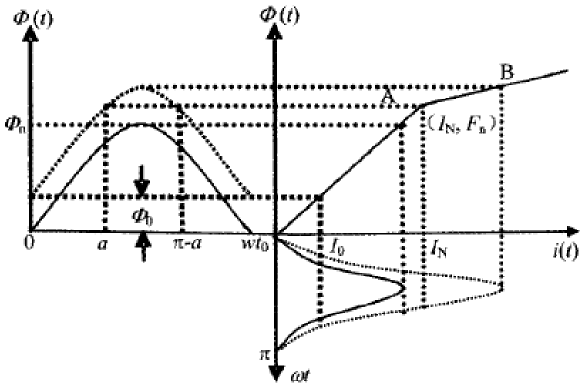


Fig. 1.1 the relationship between the excitation current and the flux

2、The simulation model of transformer under DC magnetic bias

2.1 The setup of transformer model

The model under DC magnetic bias is more complicated than that of the normal, and the distortion of excitation current is serious, which contains a large number of harmonics, and which increases the nonlinear loss and leakage inductance that is related with frequency. According to the parameters of a three phase transformer to simulate the performance of the transformer, the parameters of the transformer are shown in Table 2.1, and the transformer model is shown in Figure 2.1:

Table 2.1 the parameters of transformer

Type	ODS-30/3
Rated capacity	30/30/5 KVA
Voltage ratio	3/1.5/0.544 KV
Core type	Three frames in two columns

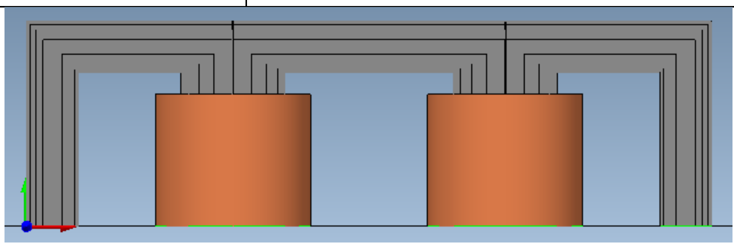


Fig. 2.1 1/4 partial of the model

2.2 The change under the DC magnetic bias of transformer

According to the simulation model of transformer in practical application, in order to see the visual phenomenon of DC magnetic bias, Figure 2.2 is magnetic field distribution diagram of the laminated core model without DC magnetic bias, the distribution of magnetic flux density is reasonable; figure 2.3 is magnetic field distribution diagram of the laminated core model with DC magnetic bias, the iron core is over saturated under the positive excitation amplitude.

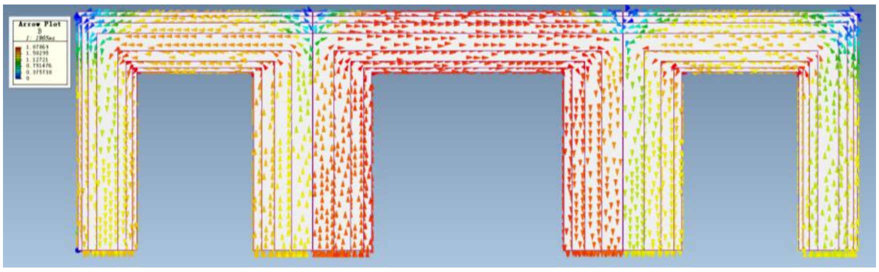


Fig. 2.2 the distribution of magnetic flux density without DC magnetic bias

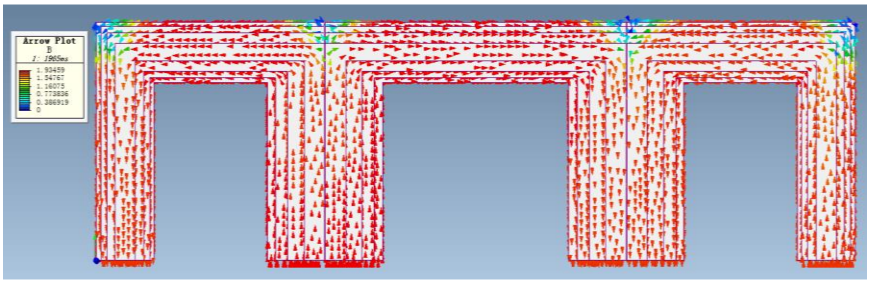


Fig. 2.3 the distribution of magnetic flux density with DC magnetic bias

2.3 The theoretical analysis

When the three phase transformer is no-load running, the three-phase magnetic circuit is independent to each other, so can write the following equations [5]:

$H_A l = N i_{mA}$（1） $H_B l = N i_{mB}$（2）

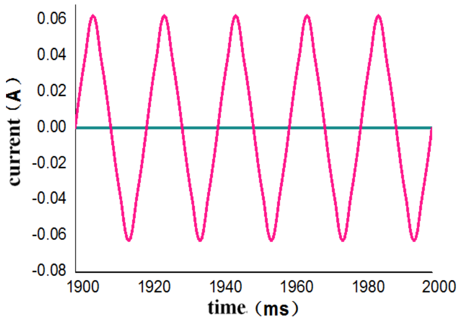
$H_C l = N i_{mC}$（3）

Among which，

$H_A = f(K_A \frac{\Psi A}{S})$（4） $H_B = f(K_B \frac{\Psi B}{S})$（5）

$H_C = f(K_C \frac{\Psi C}{S})$（6）

H_A, H_B and H_C are the average intensity of magnetic field in the transformer core; i_{mA}, i_{mB} and i_{mC} are as the excitation current; l is the equivalent length of the circuit; S is the equivalent section of the magnetic circuit; while ΨA、ΨB and ΨC are the total flux respectively; K_A, K_B and K_C are the leakage coefficient of the three-phase. The excitation current waveform of the three-phase transformer without DC voltage is shown in Figure 2.5, Figure 2.4 shows the excitation current waveform with 0.9V DC voltage[6].



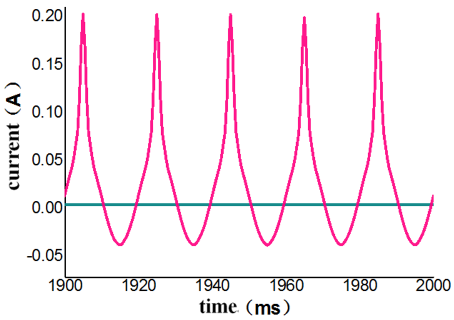


Fig. 2.4 the excitation current without DC magnetic bias

Fig. 2.5 the excitation current with 0.9V DC

Seen from the above figures, when the transformer is working in AC over-excitation case, the flux density increases, the excitation current distortion, transformer is working in the nonlinear region of the magnetization curve, excitation current waveform is top wave, and the positive and negative half wave symmetry. That is because when the transformer is under DC magnetic bias, DC and AC magnetic flux superimpose with each other, the degree of saturation increases when the AC is in accordance with the DC magnetic bias, and the saturation decreases on the other half circle, that is to say that the corresponding excitation current waveform has the asymmetry shape between positive and negative half wave [7].

3、The calculation results of the simulation

Using simulation software, selected two kinds of electrical steel grades of iron core materials, to simulate the transformer model by adding 0V, 0.5V, 0.9V DC voltage respectively.

3.1 The compare of excitation current without DC

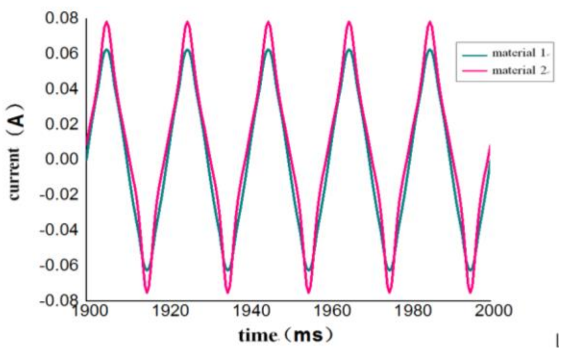


Fig. 3.1 the compare of excitation current without DC magnetic bias between two different electrical steel material

When the two material models are without DC voltage, the excitation current of the material 1 model is about 0.062A, and the peak value of the excitation current of the material 2 model is about 0.078A. Thus it can be seen that the magnetic induction intensity of electrical steel has a direct influence on the magnetizing current of the transformer, the higher the magnetic induction, the smaller the excitation current.

3.2 The compare of excitation current under 0.5V DC

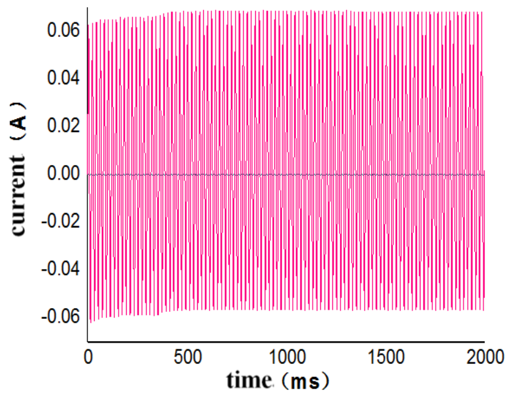


Fig. 3.2 The excitation current of Material 1

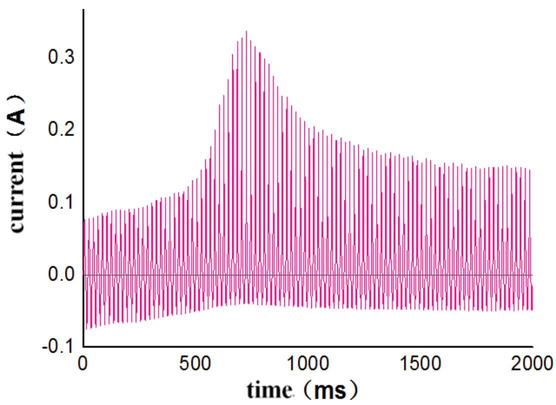


Fig. 3.3 The excitation current of Material 2

After adding the 0.5V DC voltage to the two models, the excitation current wave of material 1 model has no distortion, stable operation and stable waveform. but for material 2 model, the excitation current is distorted, although the operation is stable and the waveform is stable.

3.3 The compare of excitation current under 0.9V DC

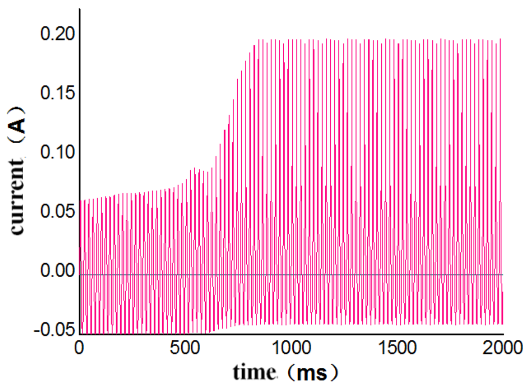


Fig. 3.4 The excitation current of Material 1

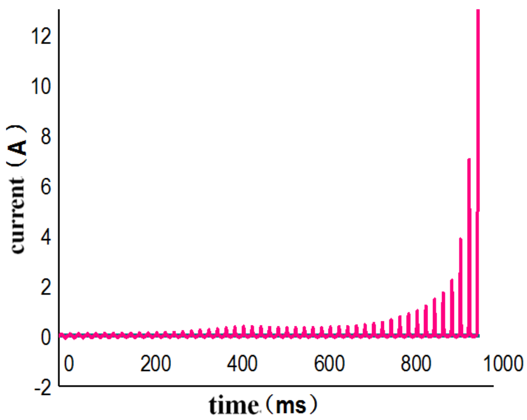


Fig. 3.5 The excitation current of Material 2

The two models are applied to the 0.9V DC voltage, and the excitation current of material 1 model is distorted, but the operation is stable, and the waveform is stable.

But for material 2 model, he excitation current is distorted, and the excitation current is too large to be over saturation, the curve is not convergent, and the operation is stopped.

Through the above comparison, with the change of the added value of DC voltage, the excitation current waveform of the transformer appears the corresponding distortion; the greater the DC voltage value, the greater the amplitude and distortion of the transformer excitation current waveform.

3.4 The interaction experiment

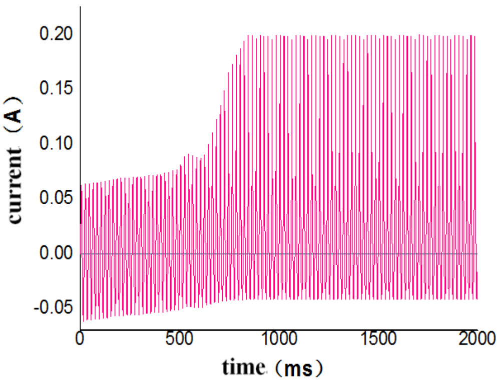


Fig. 3.6 The excitation current(loss belongs to Material 2, magnetic induction belong to material 1)

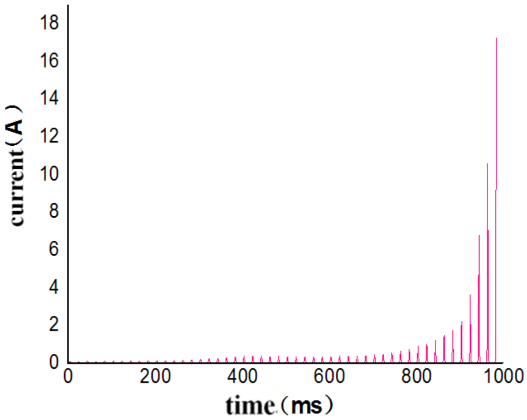


Fig. 3.7 The excitation current(loss belongs to Material 1, magnetic induction belongs to material 2)

Two kinds of material exchange B-H and B-P magnetic performance, and 0.9V DC voltage is applied to the two models respectively, the excitation current of the material 1(B-H) and material 2(B-P) model is same as the material 1, excitation distortion, stable operation, stable waveform. While the excitation current of the material 1(B-P) and material 2(B-H) model is same as the material 2, excitation current distortion, and the excitation current is too large to be over saturation, the curve is not convergent, and the operation is stopped.

Table 3.1 The performance compare between the two electrical material

Item	Loss difference（W Kg^{-1}）	Magnetic induction difference（T）
Material 1-Material 2	0.14	0.02

With the comparison performance of the two materials in table 3.1, the excitation current of transformer under normal and DC magnetic bias magnetic field is related to the magnetic induction of the electrical steel, and has nothing to do with the iron loss of the electrical steel.

4、Conclusion

(1) The magnetic induction intensity of electrical steel has a direct influence on the magnetizing current of the transformer. The higher the magnetic induction intensity, the smaller the excitation current is.

(2) With the change of the added value of the DC voltage, the waveform of the excitation current of the transformer appears the corresponding distortion; the greater the DC voltage value, the greater the amplitude and distortion of the transformer excitation current waveform.

(3) To the same three-phase transformer, with the applied DC magnetic bias, the change of the excitation current is related to the magnetic induction of the electrical steel material, and has nothing to do with the iron loss of the electrical steel material.

(4) the ability of the transformer to resist DC magnetic bias and the physical model is to be further studied.

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