

# Simulation and Analysis on Winding Deformation of a Power Transformer in Current Transformer Connecting Manner

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## Abstract

Transformer winding deformation is one of the main types of transformer faults. To check if a power transformer is being under winding deformation, the transformer can be connected in a current transformer during its testing. A transformer winding simulating model is set up under this connecting manner. Then the simulation has been performed with current source which is the frequency sweep power. The simulation results show that the winding deformation can be reflected effectively with current source method. This method lays the foundation for the realization of on-line monitoring and diagnosis of the transformer neutral directly grounded side winding.

## Keywords

Winding Deformation, Frequency Response Method, Current Source

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## 1. Introduction

Power transformer is one of the core equipment of power system. Its safe operation is crucial to guarantee the security of the power system [1] [2]. Transformer winding deformation is one of the main types of transformer faults [3] [4]. The maintenance period of transformer is more than half a year with high cost and wide influence [5]. The realization of on-line monitoring and diagnosis for transformer winding deformation will benefit for real-time record of winding running state.

Frequency response method is one of the main methods for the detection of transformer winding deformation at home and abroad, which can detect the winding short circuit impedance change of 0.2% or axial size change of 0.3% [6]. The winding is equivalent to a passive linear network when the excitation signal frequency is higher than 1 kHz. The frequency response characteristic is the outstanding property of passive linear network. The frequency response characteristic is the only for a given network. The winding equivalent parameters will be changed with the winding deformation. The frequency response curves will change reaction to the winding frequency response characteristic.

Current source is the frequency sweep power in the simulation. For the transformer neutral directly grounded

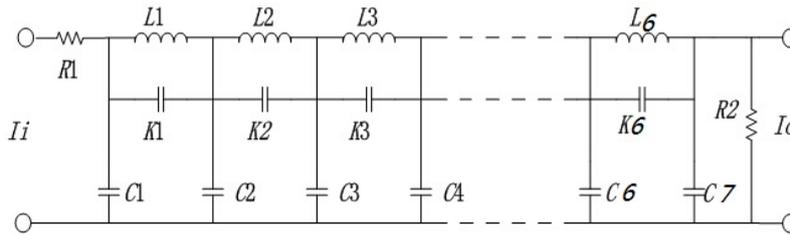
side winding which is in the online running state, current source sweep signal is applied to the grounding line through the current transformer. And the high frequency current signal is obtained in the outlet side through the current transformer. Then the frequency response curves are drawn to determine winding deformation through the comparative analysis of deformation response curves [7] (hereinafter referred as the current source method). The method will benefit for real-time record of winding running state and high sensitivity.

## 2. Establishment of Simulation Model

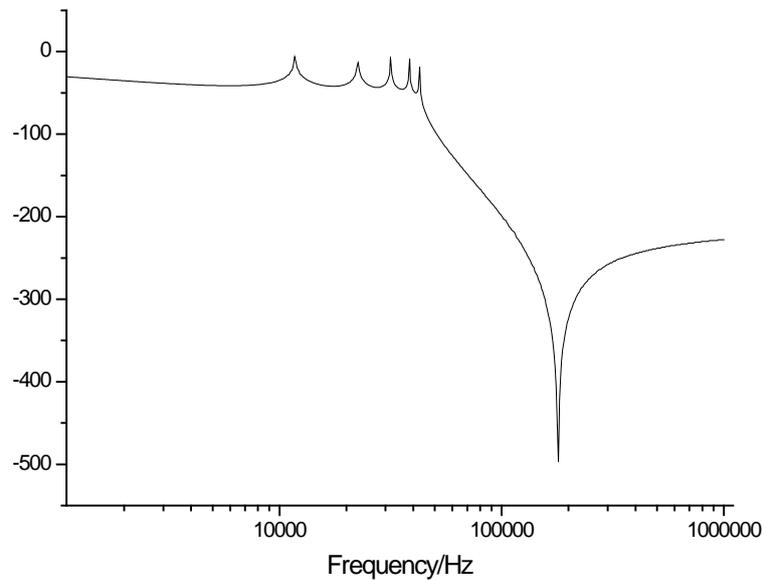
The core permeability and air permeability are almost the same when transformer is in the high frequency signal excitation (Usually more than 1 kHz). The transformer winding is equivalent to a passive linear network which consists of distributed inductance and capacitance [8] [9]. As shown in **Figure 1**, the winding equivalent model has 6 levels, and its distribution parameters are uniform distribution parameters for hypothesis.

Where,  $L$  is transformer winding inductance;  $K$  is transformer winding longitudinal capacitance;  $C$  is transformer winding ground capacitance;  $R1$  is input matching resistor;  $R2$  is equivalent resistance of output measurement loop [10]. The specific parameters of simulation model are shown in **Table 1**.

PSPICE software was used for simulation. Sweep frequency mode is order of magnitude sweep. Scanning range is from 1 kHz to 1 MHz. Scanning point is 200 in each order of magnitude. Simulation result of normal transformer winding is shown in **Figure 2**.



**Figure 1.** Transformer winding equivalent diagram.



**Figure 2.** Frequency response curve.

**Table 1.** Simulation parameters.

Parameter	Li	Ki	Ci	R1	R2
Value	40.426 mH	19.5 pF	1213.27 pF	1 $\Omega$	50 $\Omega$

**Figure 2** shows that frequency response curve is an oscillating curve with troughs and peaks. There is a peak in the frequency response curve when series resonance occurs in the winding. And there is a trough when parallel resonance occurs. The change of model parameters will cause the change of corresponding peaks and troughs. Winding deformation can be distinguished by comparing frequency response curves before and after the change of parameters [11] [12].

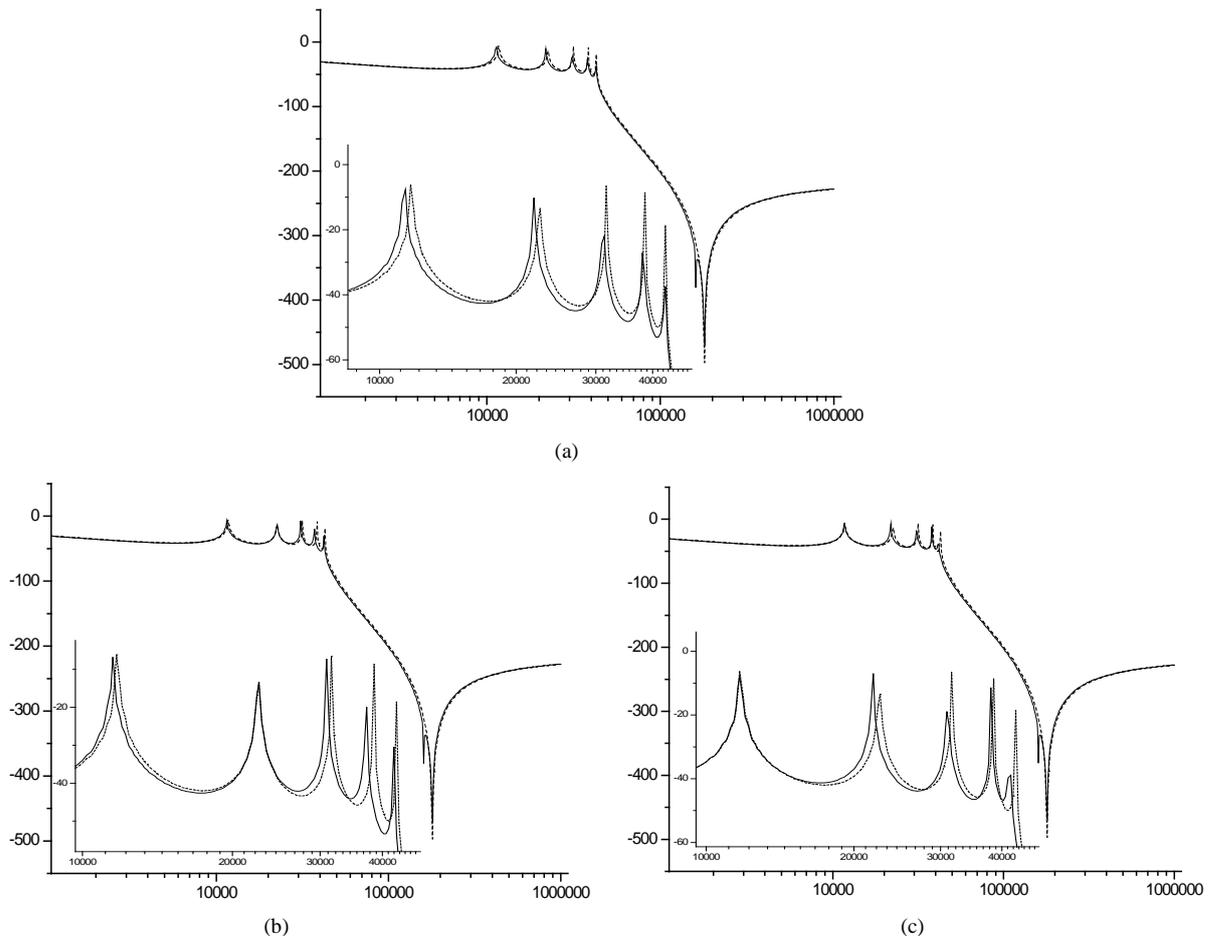
### 3. Simulation with Current Source Method

All parameters are increased of 25% respectively to simulate different parts of winding deformation. The results show that the curves are the same when the same winding deformations occur in the winding symmetrically. So the repetitive curves are not shown. The abscissa of curve is frequency which is measured in Hz. The ordinate is frequency response amplitude. Dotted line is the image under normal conditions, and solid line is the image after changing parameters.

#### 3.1. Simulation Results after Changing L

Increase L and the frequency response curves are shown in **Figure 3**.

**Figure 3** shows that peaks are offset to lower frequency and the response amplitudes are changed when the winding inductance is increased in turn. The trough amplitude in high frequency is decreased. There is a new trough in the left of the original trough. Peaks that change obviously are different when changing inductance parameters of different positions. Change L1 and peaks 1, 2, 3, 4 change large. Change L2 and peaks 1, 3, 4, 5 change large. Change L3 and peaks 2, 3, 4, 5 change large.



**Figure 3.** Simulation results after increasing L. (a) Increase L1 for 25%, (b) Increase L2 for 25%, (c) Increase L3 for 25%.

Similarly frequency response curves that L is decreased of 25% can also be made. How the change of L influences frequency response curves is summarized in **Table 2**.

### 3.2. Simulation Results after Changing K

Increase K and the frequency response curves are shown in **Figure 4**.

**Figure 4** shows that peaks are not offset basically when longitudinal capacitance is increased in turn. The trough amplitude in high frequency is decreased. And there is a new trough in the left of the original trough. Peaks that change obviously are different when changing longitudinal capacitance of different positions. Change K1 and peaks 4, 5 have a slight change. Change K2 and peaks 4, 5 change large. Change K3 and peak 4 has a slight change, peak 5 changes large.

Similarly frequency response curves that K is decreased of 25% can also be made. How the change of K influences frequency response curves is summarized in **Table 3**.

### 3.3. Simulation Results after Changing C

Increase C and the frequency response curves are shown in **Figure 5**.

**Figure 5** shows that peaks are not offset basically when C1 is changed, but they are offset to lower frequency when C2 or C3 is changed. Peaks that change obviously are different when changing C of different positions. Change C1 and peaks are unchanged basically. Change C2 and peaks 2, 3, 4, 5 change large. Change C3 and peaks 2, 4, 5 change large. The change of peak 5 is especially large when C2 or C3 changes.

Similarly frequency response curves that C is decreased of 25% can also be made. How the change of C influences frequency response curves is summarized in **Table 4**.

The above simulation analysis shows that current source method can reflect the winding deformation type effectively.

**Table 2.** Effect of L on the frequency response curve.

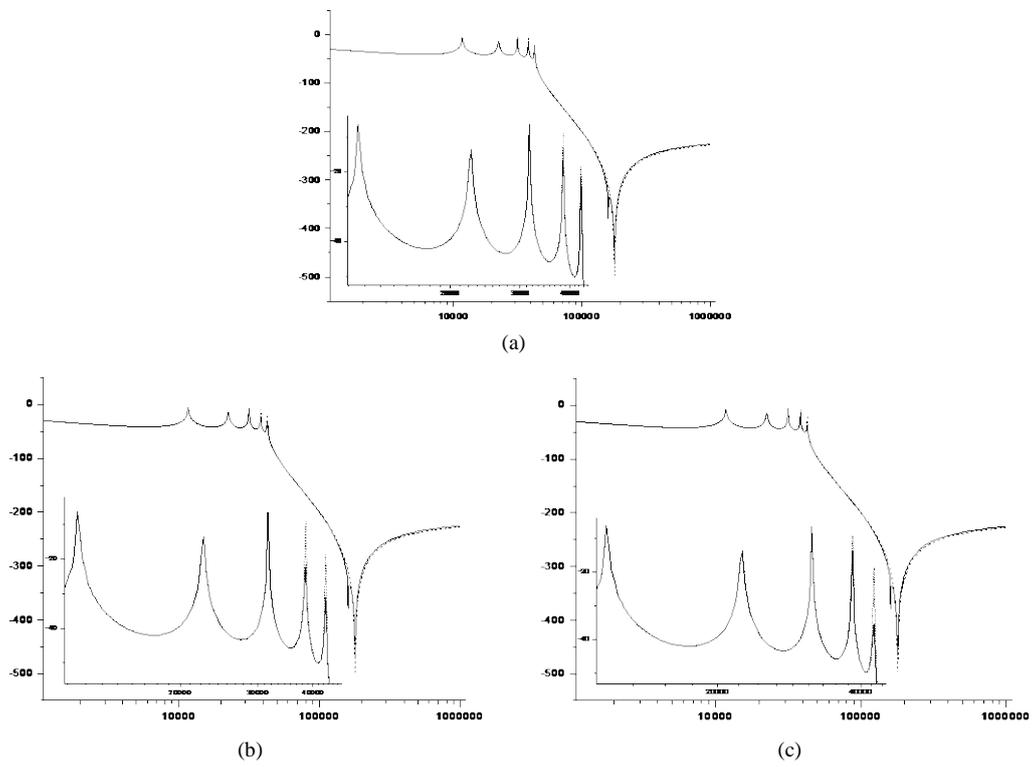
Change of L	Differences	Similarities
Increase	<ol style="list-style-type: none"> <li>1) Peaks are offset to lower frequency.</li> <li>2) A new trough appears in the left of the original trough.</li> </ol>	<ol style="list-style-type: none"> <li>1) Changes in low frequency are more obvious.</li> <li>2) The trough amplitude in high frequency is decreased.</li> <li>3) Peaks that change obviously are different when changing inductance parameters of different positions. But peaks change the same when changing inductance parameters of same positions, whether increase or decrease.</li> </ol>
Decrease	<ol style="list-style-type: none"> <li>1) Peaks are offset to higher frequency.</li> <li>2) A new trough appears in the right of the original trough.</li> </ol>	<ol style="list-style-type: none"> <li>4) The curves are sensitive to the change of L.</li> </ol>

**Table 3.** Effect of K on the frequency response curve.

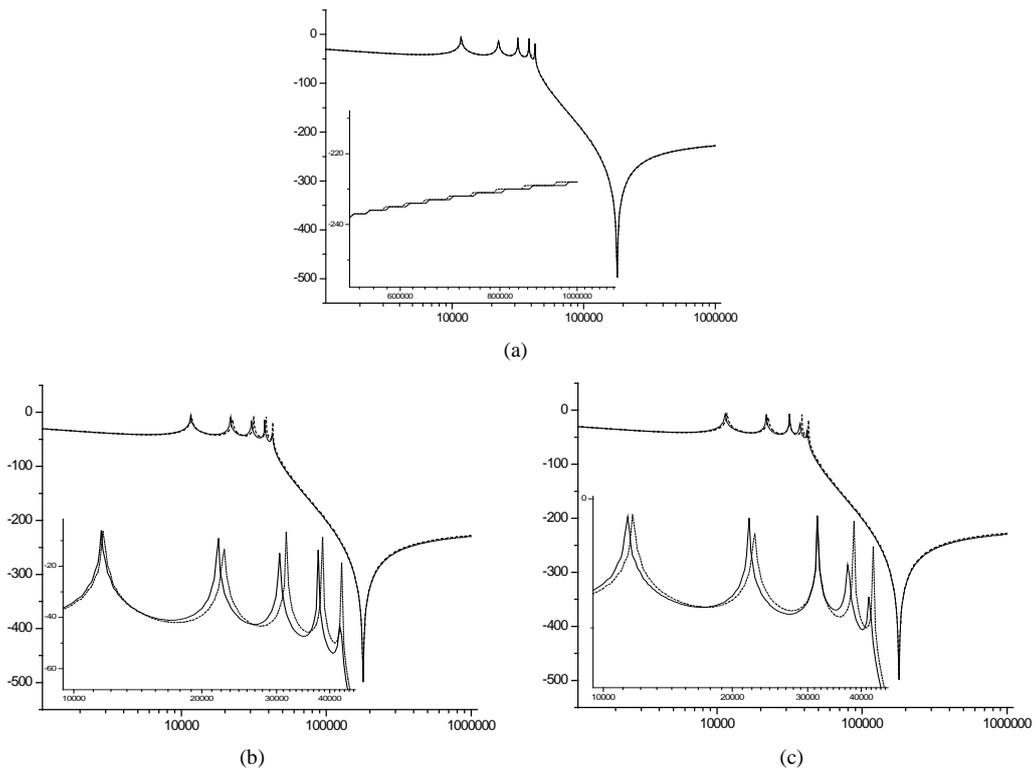
Change of K	Differences	Similarities
Increase	A new trough appears in the left of the original trough.	<ol style="list-style-type: none"> <li>1) Peaks are not offset basically.</li> <li>2) Peaks that change obviously are different when changing longitudinal capacitance of different positions. But peaks change the same when changing longitudinal capacitance of same positions, whether increase or decrease.</li> </ol>
Decrease	A new trough appears in the right of the original trough.	<ol style="list-style-type: none"> <li>3) The trough amplitude in high frequency is decreased.</li> <li>4) Changes in medium frequency are more obvious.</li> <li>5) The curves are less sensitive to the change of K.</li> </ol>

**Table 4.** Effect of C on the frequency response curve.

Change of C	Differences	Similarities
Increase	Peaks are offset to lower frequency when C2 or C3 changes.	<ol style="list-style-type: none"> <li>1) Peaks are not offset basically when C1 is changed</li> </ol>
Decrease	Peaks are offset to higher frequency when C2 or C3 changes.	<ol style="list-style-type: none"> <li>2) Frequency response curves are sensitive to the change of C.</li> </ol>



**Figure 4.** Simulation results after increasing K. (a) Increase K1 for 25%, (b) Increase K2 for 25%, (c) Increase K3 for 25%.



**Figure 5.** Simulation results after increasing C. (a) Increase C1 for 25%. (b) Increase C2 for 25%. (c) Increase C3 for 25%.

## 4. Conclusions

1) The simulation results show that current source method can reflect the winding deformation types effectively, which lays the foundation for the realization of on-line monitoring and diagnosis of the transformer neutral directly grounded side winding.

2) Current source method can't apply to on-line monitoring and diagnosis of the transformer delta connection winding. This method needs further study and discussion.

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