Residual Flux Measurement of the Single-Phase Transformer Based on Transient Current Method

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1. INTRODUCTION

This paper proposes the transient current for obtaining the residual flux density in the single-phase transformer. Specifically, firstly two DC voltage with the different polarities are applied on the exciting winding sequentially, and then the two corresponding transient response currents will be detected, and based on above information an empirical equation in regarding of the residual flux density and the transient current will be obtained.

To make sure that the applied DC voltage will not affect the former residual flux, the selecting of the DC voltage are also be presented. Both the finite element and experiment are used to verify the proposed method.

2. THE MAIN PRINCIPLE OF PROPOSED METHOD

The residual flux density distribution of the iron core, as shown in Fig. 3, can be calculated by applying the empirical formula:

\[ B_R = a_R B_{eq} + b_R (t_2 - t_1) + c \]

where \( B_R \) is the residual flux density, \( B_{eq} \) is the equivalent flux density, \( t_1 \) and \( t_2 \) are the times when the first and second DC voltage are applied, respectively. \( a_R \) and \( b_R \) are the coefficients determined by the measurements on the iron core, and \( c \) is a constant.

3. NUMERICAL SIMULATION ANALYSIS

The waveforms of source voltage, magnetic flux and transient current are shown in Fig. 1. The waveforms of transient current difference are shown in Fig. 2. The transient current difference is calculated by subtracting the transient current waveform under positive voltage from the waveform under negative voltage.

4. EXPERIMENTAL RESULTS

Table 1. Data for experimental measurement

<table>
<thead>
<tr>
<th>Measured residual flux density (T)</th>
<th>Calculated residual flux density (T)</th>
<th>Relative error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.21</td>
<td>1.27</td>
<td>5.52%</td>
</tr>
<tr>
<td>1.15</td>
<td>1.08</td>
<td>6.20%</td>
</tr>
<tr>
<td>1.08</td>
<td>1.01</td>
<td>7.14%</td>
</tr>
<tr>
<td>0.99</td>
<td>0.84</td>
<td>15.79%</td>
</tr>
<tr>
<td>0.82</td>
<td>0.79</td>
<td>3.64%</td>
</tr>
<tr>
<td>0.75</td>
<td>0.85</td>
<td>10.67%</td>
</tr>
<tr>
<td>0.52</td>
<td>0.49</td>
<td>5.27%</td>
</tr>
</tbody>
</table>

The rate of change of the transient current generated when the magnetic flux density is increased is relatively slower, thus the direction of residual flux density can be determined, and when the measurement time is 11 ms, the change of transient current difference is most pronounced and the experimental result is basically the same as the simulation. Moreover, the relative error between measured and calculated residual flux density is less than 6%.

5. CONCLUSION

- An residual flux density measurement method based on transient current is proposed. By comparing the time constant of transient current, the direction of residual flux density can be determined, and by the proposed empirical formula, the magnitude of residual flux density can be accurately measured with an error of less than 6%.
- The proposed method provides a basis for selecting the direction and amplitude of demagnetization voltage of a single-phase transformer, and can also be used for the measurement of residual flux of a three-phase transformer.