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Influence of capacitive no-load current component in large power transformers

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Abstract

No load current of large power transformers consists of active and reactive component. Active component covers hysteresis and eddy current losses in the core. Reactive component (usually called magnetizing current) creates magnetic field / magnetic flux and lags the voltage by 90°. In most models these two components are enough to describe no-load current in large power transformer at power grid frequency (50 or 60 Hz). Due to the low frequency modeling the winding capacitance are usually neglected. For higher frequencies and/or transients, ground capacitive reactances and capacitive reactances between winding turns and windings are significant and they need to be modeled and, therefore, capacitive current component occurs [1]. If capacitances can be neglected, reactive component of no load current consists only of magnetizing part and depends only on magnetic steel properties, following its B-H curve.
In this paper the presence of capacitive component of large power transformer no-load current is presented when powered by 50 Hz sinusoidal voltage. Capacitive component exist mainly as sum of the capacitive component of supplied windings and transferred currents from other windings [2], [3] Its influence on the no-load characteristic and an approach for determination of the inductive component in the no-load current based on the no-load current measurement is explained. Equivalent capacitance is compared with capacitance measurements in test field.

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Keywords: no load; magnetizing current; winding capacitance; power transformer

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1. No load current measurement and analysis

Results of the no load test for three different power transformers are shown:

- transformer#1: one phase transformer 30 MVA, 2 windings
- transformer#2: three phase transformer, 31,5 MVA, 2 windings
- transformer#3: three phase transformer, 500 MVA, 3 windings.

Tests are carried out by recording waveforms of each phase current and voltage in order to execute signal analysis for

1.1. Measurement overview

Supplied voltage was changed in ranges which cover linear part (for lower voltages) of magnetizing curve as well as saturation part. During the tests, waveforms of all supplied winding currents and voltages are recorded. In post-analysis, the frequency spectrum analysis for each waveform is performed in order to analyze behavior of fundamental harmonics and higher frequency components.

Transformers under test were powered by synchronous generator having THD of the supplied voltage below 0,5% and at rated frequency 50 Hz. All tested transformers were excited supplying the low voltage windings.

1.2. No load current analysis

For each test no load current I_{rms} and its fundamental component $I_{\mathrm{rms\_h1}}$ are calculated and shown in Fig. 1.

In same picture reactive component $I_{\mathrm{reac\_rms\_h1}}$ of fundamental harmonic in comparison with magnetizing current is shown.

Fundamental component $I_{\mathrm{rms\_h1}}$ of the current is obtained using FFT analysis of no load current waveform. From fundamental component reactive component $\mathrm{I}_{\mathrm{reac\_rms\_h1}}$ is obtained extracting only imaginary part of fundamental harmonic component using phase shift between current and voltage.

It can be seen that fundamental component $I_{\mathrm{ef\_h1}}$ of the no-load current has characteristic which differs from the characteristic of the no-load current I_{rms}, especially for transformers #1 and #3. Both of these characteristics have drop for voltages near nominal meaning that there must a component which is opposite to normal dominant magnetizing current.

If reactive part of fundamental current $I_{\mathrm{react\_rms\_h1}}$ is compared to fundamental component $I_{\mathrm{rms\_h1}}$ it can be seen that for lower voltages they have similar characteristic but at higher voltages big difference occurs. Since reactive component of the current (almost) reaches zero value where saturation begins, it can be concluded that there must be additional component which has opposite direction of usually present inductive component for magnetizing $I_{\mathrm{mag\_rms\_h1}}$.

These two last remarks lead to conclusion that there is also capacitive component $I_{\mathrm{cap\_h1}}$ in the fundamental harmonic current which can be dominant at lower voltages [2].

As shown in Fig. 1 there are two possible outcomes:

- capacitive component is much bigger that inductive component for voltages up to certain limit value (transformer #1 and #3), causing no-load current drop for voltages near nominal value;
- capacitive component is smaller than inductive component for all voltages (transformer #3), causing smaller values of no-load current .