POWER TRANSFORMER HYSTERESIS MEASUREMENT

Dennis ALBERT[1], Philipp SCHACHINGER[1] Alexander PIRKER[2], Christoph ENGELEN[3], Fredi BELAVIĆ[4], Gerald LEBER[5], Herwig RENNER[1]

Motivation

The heart of power transformers is the magnetic core, which provides the magnetic coupling between two or more windings. Any damages or changes in the transformer core directly effects the electrical and thermal behavior of the transformer. Therefore, the condition assessment of the transformer can provide additional information of the transformer condition and can help to identify negative trends in the transformer condition. The condition of the transformer core can be surveyed with a hysteresis measurement. A hysteresis measurement during the factory acceptance test or during the condition monitoring of transformers is currently not established as state-of-the-art. If a hystersis measurement would be included in the factory acceptance test, an additional 'fingerprint' of the transformer could be established. Follow-up measurements could be compared to the initial 'fingerprint' in order to identify any changes in the transformer core. Furth diagnosis procedures need to be developed for the analysis of the transformer core. In addition to the condition monitoring, the measured hysteresis can be used for electrical transient simulations of power transformers.

Hysteresis Measurement

In order to measure the transformer core hysteresis up to deep saturation the transformer need to be excited with an alternating voltage (50/60 Hz) well above the rated voltage. In order to perform the hysteresis measurement outside the laboratory, the frequency of the applied test voltage/current can be reduced while at the same the voltage is also reduced, because the flux in the transformer core is proportional to ratio of applied voltage to frequency ($\phi \propto U/f$). If the frequency is reduced to 0 Hz, so basically DC is used for the hysteresis measurement, already a small voltage and current is sufficient to drive the transformer into deep saturation. This principle is used in combination with a portable transformer test device to perform the hysteresis measurement e. g. in the substation or in the manufacturer test field.

Due to the magnetic coupling of the phases trough the core, each limb/phase of the transformer has its own hysteresis characteristic. This is especially important, when measuring a 5-limb transformer core. In case of a 3-limb y-connected transformer a measurement across the outer two limbs/windings can be performed. With the y-windings on the outer two limbs connected in series via the neutral and the terminals, the flux in the middle limb vanishes. Therefore, only the limbs of the outer two windings and the connecting yoke are measured, presenting a well-defined magnetic path. This 1-phase hysteresis measurement setup can be used for power transformer modelling or condition assessment of the core and provides a fast and easy measurement setup in case of 3-limb core. In case of 5-limb core, a comparable measurement setup is under development.

[1] Institute of Electrical Power Systems, Graz University of Technology, Inffeldgasse 18/1, A-8010 Graz, +43 (0) 316 8737-568, dennis.albert@tugraz.at, www.iean.tugraz.at
[2] VUM Verfahren Umwelt Management, Lakeside B06b, A-9020 Klagenfurt am Wörthersee, +43 (0) 64 883 42 886, alexander.pirker@vum.co.at, https://www.vum.co.at
[3] Omicron electronics GmbH, Goethestraße 20, D-91054, Erlangen, +49 (0) 913190735253, christoph.engelen@omicronenergy.com www.omicronenergy.com
[4] Austrian Power Grid AG, Wagramer Straße 19, A-1220 Vienna, +43 (0) 5032056365, fredi.belavic@apg.at
[5] Siemens Energy Austria GmbH Transformers Weiz, Elingasse 3, A-8160 Weiz, +43 (0) 664 8011771380, gerald.leber@siemens-energy.com, www.siemens-energy.com

During the postprocessing of the measurement data, the voltage is integrated over the measurement time and the well-known hysteresis plot with the flux linkage over the current is plotted.

Hysteresis Measurement Examples

We present four examples of hysteresis measurements carried out at different transformers as well as in the laboratory, during the factory acceptance test and in the substation. The major findings are:

- A demagnetization of the transformer core is necessary before the hysteresis measurement in order to measure the hysteresis characteristic, starting with the anhysteretic characteristic;
- The 1-phase hysteresis characteristic measurement from a 3-limb transformer can be used to determine hysteresis model parameters in a transient transformer model.

The major challenges can be summarized as follows:

- Demagnetizating of 5-limb transformer cores;
- Demagnetizating of multi-winding transformers.

Conclusion

To conclude, we have presented a method to measure the transformer core hysteresis from an already assembled transformer with a portable test device. The measurement can be performed in the laboratory, during the transformer acceptance test or in a substation. The measured hysteresis characteristic can be used for transient transformer models to implement the hysteresis character, e g. for studies with high transformer core saturation (inrush currents, geomagnetically induced currents, etc.). The method is demonstrated on 4 different transformer types with 3-limb and 5-limb as well as core and shell type transformers.

If only one hysteresis measurement should be performed, special attention needs to be paid to the secondary and tertiary winding connection. The secondary and tertiary winding can cause an inter phase coupling via the induced voltage and flux, respectively. Nevertheless, every hysteresis measurement requires a demagnetizing of the transformer core, in order to measure the hysteresis core characteristic starting with the anhysteretic characteristic. For 3-limb transformer cores a sufficient demagnetization method is available. For 5-limb the transformer cores the same method as for the 3-limb transformer core can be applied, but results in small remanence on the outer two limbs.