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Measurement Techniques for Transformer Diagnostic

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Abstract

Monitoring systems as basis for diagnostics open the possibility for expanding the operating time, reducing the risk of expensive failures and allows several maintenance strategies. With different monitoring techniques detailed information about the transformer condition can be received and helps to minimize the probability of an unexpected outage. New developments in the area of signal measuring and conditioning, data processing and analysing as well as environmental aspects make a more precise and detailed condition evaluation possible.

Introduction

Defects in transformers can be caused by electrical, electromagnetic, dielectric, mechanical, thermal and/or chemical load (stress). For a check of the transformer condition, different diagnostic methods are available and use chemical, mechanical, optical, thermal and electrical evaluation methods(on-line and off-line systems).

Method		Information	Comment
Oil analysis	OA	**Oil** ageing, insulation property	Routine
Gas-in-oil analysis	DGA	**Oil** and **paper** ageing, flashovers, PD, hot spots	Routine
Loss factor	tanδ	Dielectric losses in the insulation system	Routine
Furane values	FA	Ageing of the **paper** insulation	Condition determination
Degree of polymerization	DP	Ageing of the **paper** insulation	Condition determination
Partial discharges	PD	**Paper** ageing, ageing of the insulation system	Condition determination
Polarisation and depolarisation. currents	PDC	Water content in the **paper** insulation	Condition determination
Infrared measurements	IR	Overload, failure of the cooling system	Condition d., fault location
Acoustic measurements	AM	PD-detection and location	For fault location
Frequency response	FRA	Mechanical condition of the windings	After short circuits

Chemical diagnostic methods

Most internal transformer condition problems can be detected through oil analysis. New sensor technologies with higher sensitivity and new monitoring technologies have become commercially available in the last years. The methods differs between the dissolved gas anaylsis (DGA with interpretation according to Duval, Dörnenberg, IEC 599 and other methods) and the oil analysis (Furan value, moisture, neutralization value et al.).

By using chemical methods in most cases it is possible to verify failure types, which has changed since the last measurements, but it is not possible to say something about the exact failure location or the date of origin.

Test	Comments
Color	Increase in color indicates deterioration or contamination
Visual Examination	Cloudiness or sludge should be investigated
Dielectric Breakdown strength	Measures oil's ability to insulate. Sensitive to contaminations, moisture
Power Factor	Detect polar contaminants
Dissolved Gas Analysis	Detects and identifies incipient faults
Interfacial Tension	Detect polar contaminants and oxidization
Neutralization Number	Measures acidity of oil. Indicator of deterioration
Specific Gravity	Can detect contamination
Moisture Content	Moisture can damage insulation

Dissolved Gas Analysis -
Hot spots or local breakdown occur, several gases are produced and dissolved in the oil. In addition to the concentration of various gases are the ratio of some gases to each other for a failure diagnosis of importances.

Moisture in Oil -
Hence usually the Karl-Fischer titration is used which is standardized. The water content of oil can be used for the determination of paper humidity.

Humidity in cellulose -
New developed sensors measure the humidity in the cellulose. The sensor consists of impregnated paper between two electrodes and in the case of changing the humidity in the paper, the value of the capacity changes too.

Electrical diagnostic methods

For the detection of a failure, different measurement technique are in use (fig.1).

Response Analysis -
Depending on the type of application different methods - Impulse Response Analysis (IRA), Step Response Analysis (SRA) and Frequency Response Analysis (FRA) - are used. The FRA is primarily used for detection of deformation or movements of windings (fig. 2).

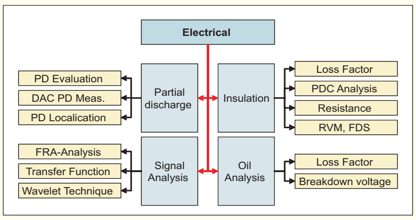

Fig. 1: Electrical diagnostic methods

Polarization and DepolarizationCurrent Analysis (PDC) -
The PDC analysis is a non-destructive dielectric testing method. It also can be used for determining the conductivity and moisture content (insulation humidity) of insulation materials in a transformer.

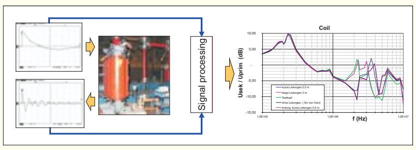

Fig. 2: Transfer function describes an transformer as an electric network

Partial Discharge (PD) -
The PD pulses generate electromagnetic waves, acoustic signals, chemical reactions, local heating and optical signals. So different techniques (sensors) can be used to detect these phenomena.
The measurement according to the IEC 60270 is a sensitive method and can be calibrated, but on-site measurements may be affected by disturbances. Some signal processing methods have been used to suppress unwanted noise.
The acoustic PD measurement uses the fact, that an acoustic signal (spectrum 10Hz up to 300kHz) as a result of the pressure build-up caused by a generated discharge is emitted.
Another possibility is the PD measurements in the VHF (very high frequency) and UHF (ultra high frequency) spectrum (fig. 3). Many types of PD impulses in transformer are sufficiently short (< nanoseconds) to radiate UHF Signals, so they generate electromagnetic waves with a high frequency spectrum up to Ghz.

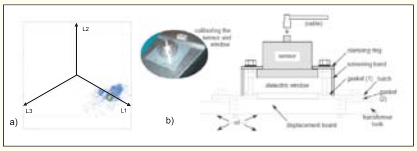

Fig. 3: a) Example of a 3-Phase Amplitude Relation Diagram (3PARD) and b) a UHF window retrofitted to a transformer

Also in connection with the electrical discharge, a radiation in the ultraviolet, visible and infrared area could be recognized. For the measurement different optical sensors and techniques can be used.

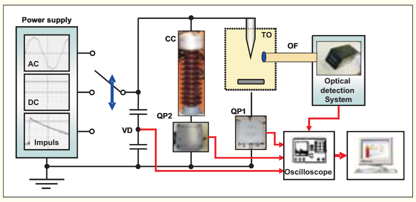

Fig. 4: Concept of the conventional and optical PD measurement
TO - test setup, CC coup. Capacity, VD - voltage divider, QP1 System - bandwidth 50MHz, QP2 - System - bandwidth 800kHz, Optical system -, OF optical fibre

At the institute an optical partial discharge measuring system was developed, which gives the basis for investigations inside of electrical equipment. The system consists of an optical sensor and fibre optic cable to transport the optical signal from inside the equipment outside to the evaluating processor unit (fig. 4). The intensity of the optical signal corresponds with the level of the partial discharge. Also the phase affiliation is given (fig.5).

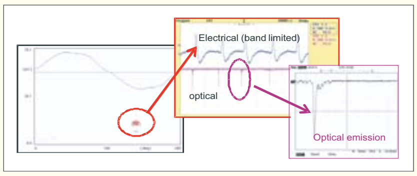

Fig.5: Comparison conventional detected PD signal (blue) and optical detected impulses (violet):

In oil the detected discharges are scattered in amplitude and shape (fig.6). It comes usually to a burst of discharges pulses, which cannot be impulse-dissolved represented with the conventional detection method (limited bandwidth system (3)). With the optical system (1) wide band conventional system (2) a detection of these single impulses is possible.

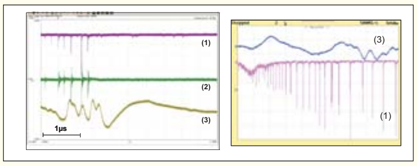

Fig.6: Comparison of the optical (1) and conventional (2), (3) detected single impulse PD signal in oil

Mechanical diagnostic methods

The tension force decreases during operation so a monitoring is useful for transformers where the risk of short-circuit is high. To determinate the existing tension force is the measurement of the transient oil pressure after applying of a current surge. Another mechanical diagnostic method is the stream analysis for controlling the cooling system. A further possibility is to analyze the acoustic vibration signal for a transformer.

Conclusion

For the transformer diagnostics are many methods available. The DGA is the most widely used method for investigating incipient faults with interpretation schemes according to IEEE and IEC standards. The PDC measurement is an non-destructive method which is capable of estimating the oil/paper condition. The FRA is a well-recognized method for the detection of mechanical displacements and deformations. PD detection is another possibility for a non destructive test. New procedures are already in use in addition to determine the intensity to permit the location of the PD-source. The UHF PD measurement has the advantage for on-site measurements with high sensitivity. The possibility of the optical detection seems to be an appropriate method for the future for specific applications with the advantage of discharge location and immunity to EMV. An possible application is the observation of critical geometrical areas in electrical equipment for example a transformer.