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Transformer Diagnostics

Power and distribution transformers as well as current and voltage transformers are mainly manufactured with paper oil insulation.

During the time of the service these insulations are ageing. The objective of this summary is to give a comprehensive comparison of the different practices used for transformer diagnosis.

The author warns the reader : In this summary the measurement problems are heavily simplified while in the reality the problems are much more complex.

The ageing procedure leads to the following electrical changes:

1. If the oil is ageing, it will become more conductive
2. During the ageing the macro molecules of cellulose (paper and board) will be depolymerised and produce water and other molecules. The moisture content in the paper will increase by diffusion of the water content into the oil. A breakdown happens normally in the oil – part of the transformer and the break down field strength is strongly influenced by the moisture content of the oil.
3. A bushing can have different problems: rupture of the insulating material or contact(s) between the layers for potential control.

   The electrical test methods are used to test, if the transformer can work without break down until the next periodical test.

   The ageing is detected by the electrical and/or chemical behaviour of the oil, by electrical tests of the allover insulation (involved board and paper) and by the test of the bushing(s).

   The electrical test methods are:

1. C and tan delta testing at power frequencies (50 or 60 Hz).

Advantages:

- The oldest method (proposed by Prof. Schering in 1914)
- Decades of experience
- Simple and fast
- Used on the same frequency as the operating frequency
- The effects of insulations between the different windings and the ground can be tested individually.

Disadvantages:

- Uses max. 12 kV (no high stress in the transformer)
- Give results only on one frequency, therefore it is difficult to analyse the internal structures.
- Heuristics: the results are interpreted based on former experience, not on a scientific analysis.

2. Polarisation – Depolarisation Analysis

Method: a voltage step is applied to the insulation to be tested and the "charging current" is recorded. Then the test object is shortened and the "discharging current" is recorded.

Advantages:

- Based on the current shapes the aging of individual internal parts can be identified: oil gap, paper part, etc.
- The method is based on a very long scientific research.
- Slower than C-tan delta method, but faster than the alternative methods (see later).
- Easy to use, PC supported diagnose
- Light weight insrument

Disadvantages:

- Time consuming test compared with C –tan delta.
- Potential distribution is not the same as at power frequency.
- Measurement of charging and discharging current possible only after one second after the voltage step or the shortening respectively. Therefore the measured quantities are related to 1 Hz or lower only providing only very approximate values for e.g. 50 Hz.

3. Low frequency current analyser.

Apply a voltage of variable frequency (1 mHz to 1 kHz) to the test object and detect C and tan delta.

Advantages:

- Delivers the C and tanδ spectrum in a large frequency domain.
- For the assessment of an insulation tanδ values for power frequencies are provided

Disadvantages:

- Very time consuming : 1 mHz corresponds to 1000 sec and the stabilisation of the current needs longer time.
- In reality it is working with a transient sine wave and therefore the results can be influenced by the way of frequency-changes
- Heavy
- Expensive

4. Recovery Voltage Meter

Charges the test object for successive increasing times, than discharge it during the half of charging time, than open the object and measures the so called "recovery voltage" on the terminals. The maximum of this recovery voltage is traced in function of the charging times.

Advantages:

- For simple structures (without oil gap) with one time constant, gives an estimation of the moisture content of the paper part.
- Light
- Low cost

- In the above mentioned simple case a diagnostics by the "operator eye" is possible.

Disadvantages:

- In complex cases the diagnosis is wrong : Transformers with oil gap can show a "RVM" spectrum related to high moisture content also in cases where the structure is really dry.
- Very time consuming because after every charge-discharge – measurement cycle the insulation must be completely discharged.
- Not possible to distinguish between insulations of different windings or between windings and tank.
- If the leakage in the test object is very low, the method does not work

5. Partial discharge

The only method to stress an insulation equal as under operating conditions.

Advantages:

- Works at nominal voltage
- Can detect ruptures as well as small defects in an insulation

Disadvantages

- Expensive mobile power supplies are necessary
- Engineering efforts needed to eliminate disturbances / interferences

6. DC Resistance

It is the same as polarisation current measurement. If the current in the first few seconds is measured, the resistance shown is mainly the resistance of the oil gap. After long time (hours for a new transformer) the measured resistance becomes high towards its leakage value, which is approx. the resistance of the paper insulation.

Advantages:

- A simple method.

Disadvantages:

- It delivers poor information, mainly something of oil resistivity. The paper part is not detected, therefore even if a "good" value is measured, the paper part can be very bad.

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