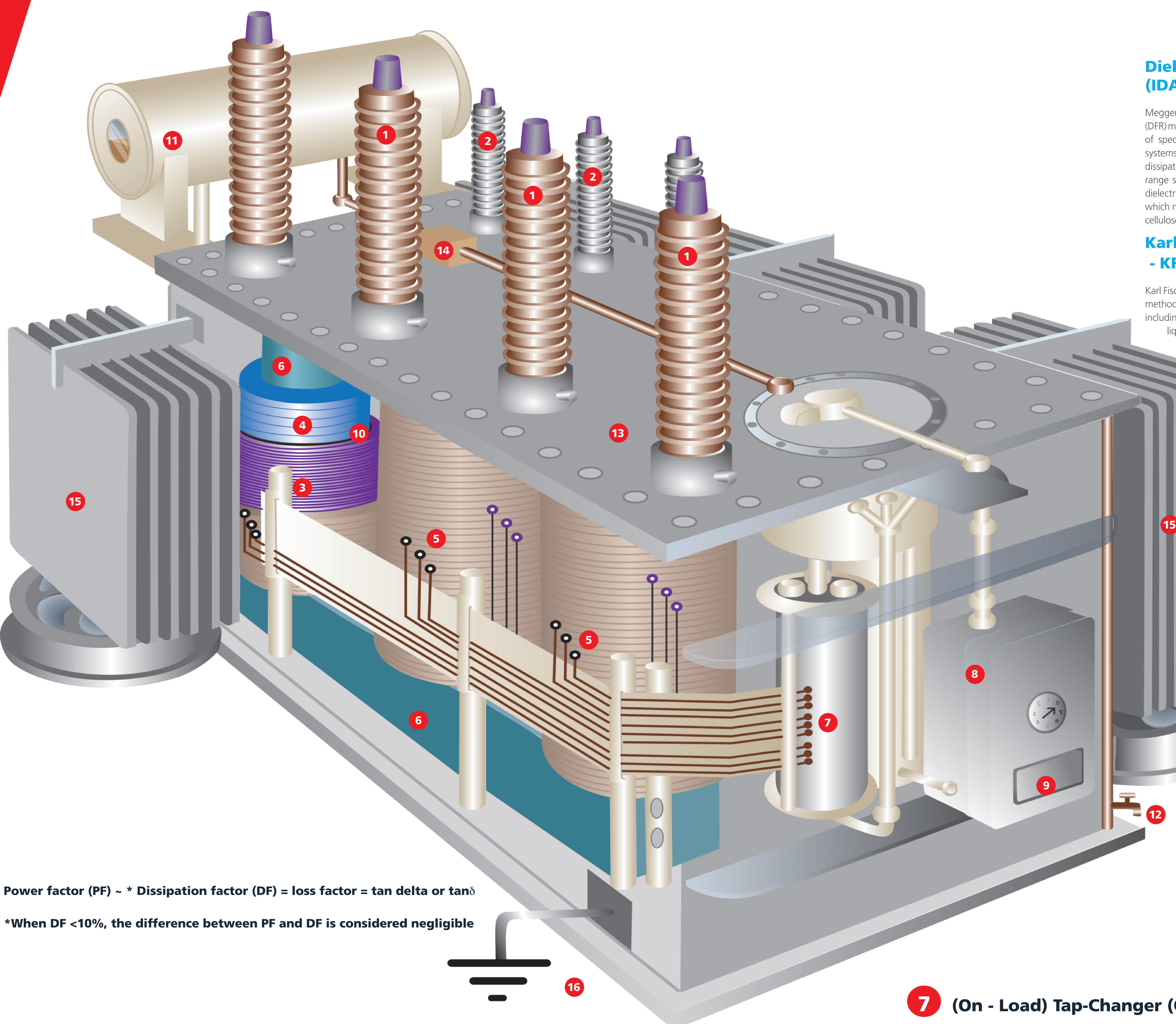
Power transformer testing

Megger

Power on



Power factor (PF) ~ * Dissipation factor (DF) = loss factor = tan delta or tanδ

*When DF <10%, the difference between PF and DF is considered negligible

Dielectric Frequency Response - (IDAX, VAX, TRAX and Delta)

Megger has a long history of making dielectric frequency response (DFR) measurements. DFR is used to investigate insulation properties of specific materials and material combinations, e.g., oil-paper systems. A DFR result is obtained from a series of power factor/ dissipation factor (PF/DF) measurements made over a frequency range such as 1 mHz to 1 kHz. The IDAX system measures the dielectric response of the insulation in transformers and bushings, which may be used to determine, e.g., the moisture content in the cellulose insulation and oil conductivity.

Karl Fischer Titration - KF LAB / KF875

Karl Fischer moisture in oil test sets operating with the coulometric method are widely used for measuring the water content of samples including electrical insulating oils, transformer oils, insulating liquids, petroleum products, silicone oil and organic liquids.

Sweep Frequency Response Analysis - FRAX

Sweep frequency response analysis can detect a mechanical/ physical change inside the transformer. Such faults usually occur within the windings, leads or tap changers, and are often caused by a short circuit. Transport, earthquakes and lightning can also cause mechanical faults. With FRAX, you can recognise winding deformations, separations, short-circuited turns, open windings, loose or interrupted terminals, core connection problems, partial winding breakdowns, faulty core grounds or displacements of the core.

DC Insulation - MIT/ S1 Series, IDAX

Insulation resistance measurements are useful to assess the core insulation of a transformer and investigate whether multiple/ unintentional core grounds are present. Insulation resistance measurements quickly detect decomposition through aging and operation and are typically the first test performed when a transformer has faulted. Insulation resistance measurements are often conducted between the primary and secondary windings. The higher the resistance, the better the insulation – and the higher the test voltage, the better the accuracy of the insulation quality result. Depending on the specific test set, the MIT/S1 series can offer up to 5kV, 10kV or 15kV test voltages. The Guard Terminal technology enables accurate measurements even at high leakage currents, which result mostly through impurities that can be found given the surface of the sample.

Power factor/dissipation factor (PF/DF) of the Insulating Liquid – OTD

Monitoring and maintenance of oil quality is essential in ensuring the reliable operation of oil-filled electrical equipment. One of the fundamental tests of oil quality is the PF/DF test, which is a measure of the condition of the dielectric, where a high value in the measurable range can indicate contaminates. The Oil Tan Delta (OTD) measures the PF/DF, specific resistance and relative permittivity of insulating liquids.

Short circuit impedance - TRAX

TRAX can quickly and easily measure a transformer's short circuit impedance to check for deformation or movement of the windings. The results can be compared with the transformer nameplate, but a 'fingerprint' comparison is much more accurate. A very revealing diagnostic is obtained by performing short circuit impedance measurements on each phase and comparing the measured results to the average phase impedance. These results should be within a maximum of 2 to 3% of the average; in many cases the variation will be less than 1%. It is recommended to carry out a short circuit impedance test after a short circuit event, if the transformer was physically moved, or to establish an initial benchmark result.

Frequency Response of Stray Losses - TRAX, FRAX

FRSL is a tool that allows detection of short circuit conditions between individual strands within a conductor bundle. It is also sensitive to conditions that result in a change of losses that occur in conductive, structural components that lie in the path of leakage flux (e.g., transformer tank, clamping structure, tie plates).

Dielectric breakdown voltage - OTS-Series

Clean insulating oil is fundamental to the safe operation of transformers. Over time, oil can accumulate moisture, gases, sediments and suspended solids, which change the quality of the insulation. The test container within the OTS series is filled with an oil sample, and the test voltage between two electrodes is increased until an electrical breakdown occurs. The OTS automatically evaluates these results according to the current standard – all current standards are stored in an internal database.

Exciting current - TRAX, Delta, IDAX, TTRU3, TTR, MWA

Exciting current testing is used to assess a transformer's magnetic circuit, its turn-to-turn winding insulation, and tap changer(s) condition. It is particularly valued for its ability to detect partial turn-to-turn short-circuited conditions (which sets it apart from other tests that are sensitive to short-circuited winding conditions) and is sensitive to tracking problems in the insulation (e.g., winding to ground or phase to phase). It is sensitive to core defects (either from time of manufacture or due to subsequent damage), changes in the transformer core's characteristics, core lamination insulation damage, and abnormal circulating currents in the core. Analysis of the results is done by comparing the measured current and Watts between phases and for load tap-changing transformers, by additionally comparing the current and Watts measured at each tap position within a phase

Winding resistance TRAX, MWA, MTO

Winding resistance measurements are vital for the assessment of the intended current carrying path between bushing terminals, and may reveal problems such as loose or defective connections, broken strands or high contact resistance in tap changers. The most common method used to evaluate the test results is a comparison of the resistance values measured between each pair of bushing terminals. Differences between phases are usually less than 2 – 3 percent. At the end of the measurement, TRAX will automatically demagnetise the transformer core.

Turns Ratio - TRAX, TTRU3, TTR, MWA, Delta, CDAX

Turns ratio testing is useful to detect open- and short-circuit conditions in transformer main and tap windings. It also provides a quick verification of the most fundamental operational characteristic of a transformer – its ability to transform voltage as anticipated. Results are compared with the nameplate ratios. Phase deviation and excitation current are concurrently measured.

Demagnetisation- TRAX, MWA, MTO

A transformer should be demagnetized after each winding resistance measurement. The condition of a residually magnetized core is not a failure but may result in potentially damaging in-rush currents when the transformer is energized with multiple implications to the transformer and the power system. A magnetized core may also influence certain off-line, diagnostic test results (e.g., SFRA and exciting current) such that meaningful conclusions about the condition of the transformer cannot be accessed. TRAX allows both manual and automatic demagnetization and provides the before and after % of saturation values.

Power factor/ dissipation factor (PF/DF) - TRAX, Delta, CDAX

A PF/DF test measurement with an AC test voltage up to 12 kV at line frequency (50/60 Hz) provides a general assessment of insulation quality. The measured results are compared to previous test results or may be compared with nominal values according to VDE, IEEE, ANSI, etc., assuming that the result has been accurately corrected to a 20°C reference value. Further diagnostic insight is provided through recommended PF/DF test measurements made at multiple frequencies (1 – 500 Hz), a capability of the Megger TRAX and the Megger Delta 4000 series power factor instruments. The TRAX and Delta offer additional technically differentiating power factor test features such as determination of a transformer's individual temperature correction (ITC) and an automatic voltage dependency detector (VDD) that alerts when tan delta tests should be made at additional test voltages.

Current transformers - TRAX, MRCT

Bushing CTs or separate current transformer installations may be tested with TRAX or the MRCT, a dedicated current transformer test instrument. TRAX determines the knee-point voltage of the current transformer as well as its ratio, winding resistance, etc.

OLTC Diagnostics - TRAX, (also, Delta, MWA, MTO, TTRU3, TTR, IDAX)

Because the tap-changer is a moving component, the switchgear undergoes constant wear and is therefore a frequent source of faults within a transformer. With a dynamic resistance measurement, TRAX detects inconsistencies, incorrect operation or changes in the contacts and duration of the switching. Before the transformer is commissioned, a measurement should first be carried out to provide a 'fingerprint', to later help identify the type and location of the disturbance.

1 High Voltage (HV) Bushings

Bushings provide an insulating path for energized conductors to enter a grounded electrical power apparatus such as a transformer. High voltage (HV) bushings are connected to the high voltage power lines and to the high voltage winding(s) of the transformer. An HV bushing has either a potential or a test tap electrode, depending on the rated voltage of the bushing. The tap electrode is located at the base of the bushing just above the bushing's flange; it enables isolation of the bushing's insulation from ground so that the bushing may be tested separately from the transformer's insulation (which is desired) without otherwise having to physically remove the bushing from the transformer. HV bushing naming conventions vary by regions of the world.

2 Low Voltage (LV) Bushings

Low voltage (LV) bushings are connected to the low voltage power lines and to the low voltage winding(s) of the transformer. A LV bushing may or may not have a test tap electrode, generally depending on the rated voltage of the bushing. Naming conventions for LV bushings vary worldwide.

3 Primary (typically the High Voltage) Winding

A voltage is applied on the primary winding, generating a magnetic flux in the core, which induces a voltage in the secondary winding. The number of turns affects the amount of induced voltage. The ratio between primary and secondary voltage is determined by the ratio of turns between the windings

4 Secondary (typically the Low Voltage) Winding

The number of turns of the secondary winding is less than on the primary winding. The conductor cross section is greater as higher currents flow. The resistance is also smaller. The number of turns (N) affects the level of the induced voltage. The ratio between the primary and secondary voltage is equivalent to the ratio of turns. The ratio between the primary and secondary current is inversely proportional to the turns ratio: $I1 / I2 = N2 / N1$.

5 Regulating winding with tapping points

Ideally, a transformer must constantly maintain its defined voltage level. In practice, however, load and voltage fluctuations on the grid do occur. To compensate for these variations, the gear ratio needs to be adjusted. The number of current-carrying coils in the control winding should be changed via the tap points, which are directly connected to the tap changer.

6 Transformer Core

The core of a transformer consists of insulated steel laminations and has a closed shape. The horizontal segments are called 'yokes' and the vertical segments are called 'limbs'. The layered structure reduces eddy current losses. The combination of the core, windings and insulation form the active part of the transformer.

7 (On - Load) Tap-Changer (OLTC)

Within the tap-changer the ratio of the primary and secondary windings are finely tuned, with the load-tap changers switching under load, without interruptions to the current flow. The OLTC consists of a diverter switch and resistors (resistive-type OLTC) or coils (reactive-type OLTC), which limit the short circuit current during switching. Resistive type tap-changers, common in Europe, Asia, Africa and South America, are connected to the HV winding of the transformer. Reactive type tap-changers, common in North America, are almost always connected to the LV side of the transformer. The tap-changer is either mounted inside the tank or it is housed externally depending on design of the transformer.

8 Control Box with Drive

The control box is used to control the on-load tap-changer. It contains the tap-changer controller and the drive. The controller measures the voltage level on both the high and low voltage sides. Once the voltage band is set, there is an automatic operation. The tap-changer now switches to either a higher or lower ratio.

9 Nameplate

The nameplate contains lots of information about the transformer, including:

- Year of manufacture
- Rated power
- Rated frequency
- Short-circuit voltage
- Vector group
- Cooling
- Oil weight
- Volume in operation
- Insulation levels
- Maximum short circuit duration
- Rated voltage
- Weight
- All other important information about any added components, such as tap-changers or current transformers.

10 Paper insulation (Cellulose)

The insulation system of a power transformer consists of oil and cellulose. Cellulose is solid insulation (paper and pressboard) that is typically processed using the Kraft method. A major function of these insulation materials/dielectrics is to provide electrical isolation between energized parts of the transformer. However, oil and cellulose serve additional roles as well. For example, the cellulose serves a mechanical function by supporting the windings and a thermal one by creating cooling ducts (via radial spacers and barriers). Meanwhile, the transformer oil also (1) provides sufficient cooling/heat transfer, (2) preserves the core and coil assembly by filling voids in the cellulose, and (3) minimizes the contact of oxygen with cellulose and other materials that are susceptible to oxidation.

11 Insulating Oil Conservator

An oil conservation system is one type of preservation system, which is used to isolate the transformer's internal environment from the external environment while at once allowing the transformer to "breath" due to normal variations in pressure. The conservator is directly connected to the tank. In operation, the transformer is heated and expanding, overflowing oil flows into the conservator. Upon cooling, the oil flows back into the transformer tank. There is not a vacuum in the conservator since aiflows from the outside into the conservator. The most important feature of a conservator is that it reduces the surface area of the oil exposed to atmospheric air. Conservators may have a rubber bladder inside that expands or retracts due to temperature of the oil versus the ambient temperature; such a bladder eliminates exposure of the oil to air. Dessicant breathers using a material such as silica gel may also be installed, which serves to remove moisture from the air as it passes through the tank. There are also sealed-type transformers and those with positive pressure systems.

12 Oil Drain Valve

The oil drain valve is located at or near the lowest point of the tank and often serves as an oil sampling point. Oil samples can be used to test the dielectric strength of the oil, determine Tan Delta (loss factor) or to determine water content by the Karl Fischer titration. An oil sampling procedure should be carefully followed to obtain a sample representative of the bulk oil in the transformer. This will include provisions for cleaning the drain valve inside and out to avoid sample contamination and thoroughly flushing the valve since contaminants in the transformer, such as water and particles, will eventually settle out and collect on the bottom of the tank near the drain valve.

13 Transformer Tanks / Lids

The transformer housing is basically an oil filled tank. The top cover plate forms the cover, and the active part of the core, windings and insulation are completely immersed in insulating oil within this tank. The insulating oil for its part consists of highly refined mineral oils. Modern transformers may use silicone oil or ester. The oil, for reasons of environmental protection, is collected if it is spilt so it cannot seep into the ground.

14 Buchholz Relay

A conservator makes possible the use of a Buchholz relay. The Buchholz relay protects the transformer. Overheating can quickly lead to insulation faults, and this produces gases in the oil space. The gas bubbles rise to the highest point of the tank and expand. The relay sits between the main tank and the conservator. When small rates of gas production are detected they are reported or alarmed, while for large defects the relay may in some cases be set to trip the transformer immediately.

15 Cooling Unit

While a transformer is an extremely efficient device, some energy is lost to heat, which is dissipated by cooling systems. A popular dual cooling rating is ONAN/ ONAF. 'ONAN' cooling describes a totally self-cooling arrangement, where the oil flow through the radiators is due to natural convection, while with 'ONAF' cooling, the heat is dissipated through the additional aid of fans. In each case, the temperature of the system affects the performance the transformer.

16 Grounding

The transformer tank is designed for personal safety and the safe operation of the entire system. As with all electrical equipment, the system must be earthed, making it safe to touch during operation. The transformer core and tank is electrically grounded. For a review of the common ground connection, it is recommended to set the test voltage at a different frequency to that of the mains (between 50 – 60Hz). Since the measurement is otherwise affected by induced noise, keeping the mains frequency can lead to inaccuracies. Megger provides a ground resistance tester with the ideal test voltage.