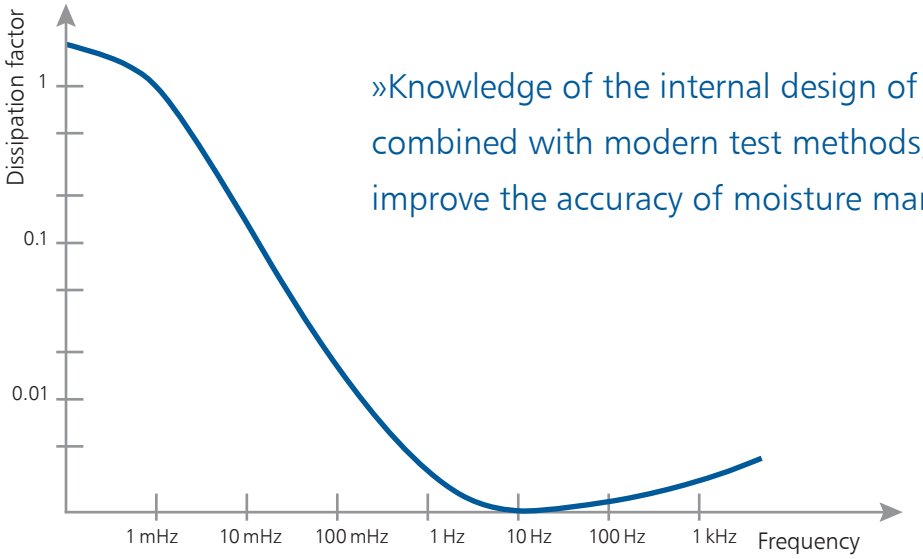
Tracking down the water

Effective management of water content in power transformers—part 1

Wilson Transformer Company is an Australian leading manufacturer of power and distribution transformers. As presence of water is an important factor in the aging of insulation, it is essential that the water content of the transformer oil and insulation system is effectively managed. DIRANA, the Dielectric Response Analyzer from OMICRON assures an accurate measurement of water content.

Authors: Kenneth Budin and Meng Lee, Wilson Transformer Company, Australia

There are different reasons why water can be found in transformers. Some water, typically between 0.5 % and 1.0 %, remains in the thick insulation of a transformer after the manufacturing process is completed. Water can also be introduced due to poor sealing, such as leaking gaskets or flaws in welded seams and is the natural by-product of the aging of cellulose insulation. As paper degrades it gives off CO_2 and H_2O so even if all other sources of water are controlled, water will be generated as the transformer insulation



Dielectric response measurement graph

»Knowledge of the internal design of the transformer, combined with modern test methods, can greatly improve the accuracy of moisture management.«

ages. In free-breathing transformers water is also introduced due to the ingress of air, even where a silica gel breather is fitted. Poor preservation practices during transformer assembly or maintenance can also lead to significant moisture contamination.

Water can be stored in the insulation, can be dissolved in the oil and can be found as free water lying on horizontal surfaces inside the transformer. It is important to note that the movement of water is dynamic, and that water is continuously moving between the oil and paper insulating system due to the temperature cycling of the transformer. The temperature is affected by load and ambient conditions thus the detection and accurate measurement of water levels is therefore quite complex.

Possible serious damage

Water is the most important factor in the aging of insulation. The presence of excessive moisture, often in the form of free water, can also lead to catastrophic failure due to partial discharge, tracking or flash-over between conductors or from a conductor to ground. Thus in order to maximize the life of transformer assets it is essential that the water content of the transformer oil and insulation system is efficiently managed.

Effective moisture management

The best strategy for moisture management is prevention. Besides the use of preservation systems, effective drying processes such as vapor phase can reduce moisture in the insulation during manufacturing to less than 0.5 %. During installation or maintenance best-practice procedures can be used to prevent or minimize moisture contamination.

Existing transformer conservators can be modified at any time to eliminate contact with air, for example retro-fitting of a new conservator with a Conservator Oil Preservation System (COPS), or a ground mounted nitrogen-bag connected to the existing breather pipe.

Moisture detection methods

To determine the performance and aging of the asset, insulation behavior is a main indicator. Wilson Transformer Company uses different methods to determine the degree of moisture contamination. In the case of an oil-insulation system an oil sample is taken using a glass syringe. Due to chemical reaction the amount of water molecules can be measured and with an equilibrium diagram the water content of the solid insulation can be estimated. However, older units cannot be tested

Kenneth Budin

Kenneth Budin is Services Manager for Wilson Transformer Company and Director of TJ|H2b Analytical Services Pty Ltd., both based in Melbourne / Australia, and is a member of CIGRÉ Australian Panel A2.

with this method as equilibrium conditions change during aging. Another approach is the measurement of Polarization and Depolarization Currents (PDC) or the Frequency Domain Spectroscopy (FDS). Both measurements show deficiencies in the insulation and can analyze the water content. Measurement results can then be interpreted by using a database. FDS shows the dissipation factor over a wide frequency range from 100 μHz up to 1 kHz, from which the water content can be derived. This measurement takes a lot of time though, since the time of oscillation rises as the frequency reduces.

DIRANA gives best results in case studies

OMICRON's DIRANA accurately analyzes the dielectric response in half of the usual measurement time by effectively combining the two measurement methods FDS and PDC. Wilson Transformer Company compared the results of conventional measurement methods with the test results of DIRANA. Different case studies are shown: A transformer directly after manufacturing, one which had been damaged during shipping, one from which oil had been stolen and an aged transformer.

The transformer tested right after manufacturing was considered to be dry as the usual measurements showed less than 0.5 % water in the insulation. The measurement with DIRANA confirmed those results.

In the case of the transformer damaged during shipping there was quite a different outcome. Although a water-in-oil-test indicated 5 % water in the paper insulation, DIRANA indicated a water content of about 1 %—a value that is expected for new transformers. DIRANA's test results were found to be correct after further testing. Without the DIRANA measurement we would have assumed that this transformer's insulation was very wet leading to an unnecessary expense.

In the case of the stolen transformer oil in Malaysia, DIRANA also indicated a water content of less than 1 %, although the insulation was expected to be wet as a result of the oil loss. Later inspection revealed the DIRANA measurement to be correct. The COPS bag for this transformer had been ruptured, with part of the bag subsequently sealing the Buchholz pipe and preventing insulation contamination through moisture ingress.

Tests on an aged transformer also showed DIRANA measurements to be more accurate than other methods. A transformer

Measurement methods to detect moisture in the solid insulation of power transformers

Karl Fischer Titration on paper/pressboard samples
Measurement of the amount of water in a paper/pressboard sample due to chemical reaction.
- \+ Having the highest accuracy, this is the typical benchmark for other methods.
- − Sampling not possible during service.
- − Humidity can influence result, as soon as the sample is exposed to the air.

Karl Fischer Titration on oil samples and use of equilibrium chart
Measurement of the amount of water molecules in an oil sample due to chemical reaction. An equilibrium diagram is used to estimate the water content of the solid insulation.
- \+ Easy sampling, even online.
- − Sampling critical, as for paper/pressboard samples.
- − Aging changes equilibrium conditions, for example diagrams are not valid anymore for older units.

Capacitive probes
Measurement of capacitance change due to water ingress into hygroscopic polymer film.
- \+ Easy application, no transport to laboratory necessary.
- − Relative water saturation is measured, not water content itself.
- − Calibration necessary.

Recovery Voltage Method (RVM)
Measurement of recovery voltage after charging the insulation with DC voltage. Estimation of water content from time constant in the polarization spectrum.
- \+ Simple setup, as for traditional dissipation factor measurements.
- − According to CIGRÉ, the interpretation scheme based on dominant time constant is incorrect.

Polarization and Depolarization Currents (PDC)
Measurement of polarization and depolarization currents after applying a DC voltage to the insulation. Interpretation of measured curve using database.
- \+ Simple setup, as for traditional dissipation factor measurements.
- \+ Proven interpretation scheme.
- − Only times greater than 1 s can be measured.

Frequency Domain Spectroscopy (FDS)
Dissipation factor measurement of solid insulation in a wide frequency range (100 μHz to 1 kHz). Interpretation of measured curve using database.
- \+ Simple setup, as for traditional dissipation factor measurements.
- \+ Proven interpretation scheme.
- − Long measurement duration for low frequencies.

Singapore—Transformer damaged during shipping: DIRANA indicated that there was a water content of about 1 %. When this was combined with other electrical test results the transformer was found to be electrically sound. A significant amount of water had not spread to the paper insulation.

Malaysia—Oil stolen from transformer: The team in front of a power transformer performing a dielectric response test with DIRANA in wet weather.

manufactured in 1965 was considered to be dry as a water-in-oil test indicated about 2 % water in the paper insulation. However, this test did not take into consideration the fact that the oil was recently replaced and moisture equilibrium may not have been achieved. Only the measurement with DIRANA indicated water content in the insulation. In this case the level was approximately 5.4 %, which is classed as extremely wet. A combination of other electrical test results again confirmed that the measurement with DIRANA was correct.

Fast and accurate diagnosis

Moisture contamination of power transformers is detrimental to their serviceability and life expectancy. Proactive action at the time of specification and purchase can greatly reduce the negative effects of moisture and oxygen. Accurate measurement of water in insulation is a complex process. Knowledge of the internal design of the transformer, combined with modern test methods, can greatly improve the accuracy of moisture management. OMICRON's DIRANA compensates for aging effects and makes highly accurate measuring possible, independent from achieving equilibrium. Simultaneously measurement with DIRANA saves 50 % of the measuring time required by conventional measurement methods.

Read more about the monitoring of water content during the drying process in the next issue of the OMICRON magazine.

VIDEO

More information on the analysis of moisture content in transformers on www.youtube.com/omicronenergy

Meng Lee

Meng Lee is an Electrical Engineer for the Services Department, Wilson Transformer Company, Australia.

Wilson Transformer Co.

Wilson Transformer Company is a leading Australian manufacturer of power and distribution transformers. It produces transformers to standard designs as well as custom designs up to 400 MVA / 400 kV. Wilson also manufactures offshore in Malaysian and Saudi Arabian joint ventures.

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