Has transformer oil testing reached its “sell by” date?

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Transformer oil testing has traditionally been the preserve of laboratory procedures. New technology permits portable on-site and continuous on-line tests to be conducted. The article reviews the relevance of laboratory testing in the light of these developments.

Transformer oil testing has been an excellent tool for preventative maintenance on oil cooled transformers. It has permitted extended service life by giving a measure of both oil and solid insulation condition, as well as identifying the presence of incipient faults. But some transformer defects develop from a non-detectable stage to full catastrophic failure within the typical period between tests. It therefore becomes a matter of chance whether these defect types are detected with interval based testing. Often they are not, with many examples in the literature [1], [2]. This means that typical periodic oil testing alone is not sufficient to ensure prevention of failure.

On critical units where significant consequential costs are associated with premature or unexpected failure, this becomes an important consideration. One way around the problem is to greatly increase the frequency of testing, but this carries with it the consequences of complexity and cost. This is when predictive diagnostic technology becomes a preferred solution. It combines the early detection of fast developing defects with diagnostics, failure prognosis and consequent triggering of alarms when risk of failure is indicated. This means that maintenance engineers can be alerted to fast incubating defects and take corrective action before they mature.

But traditional oil testing methods are strictly off-line sampling and laboratory techniques. They are therefore preventative maintenance procedures. However, modern technology has permitted the development and commercialisation of mobile on-site test methods. By extending these to continuous on-line oil testing, in combination with intelligent electronic devices which can record and trend results and trigger alarms, we now have predictive diagnostic tools which can eliminate the risks (gambling) associated with interval testing. On-line testing also eliminates the considerable problems associated with oil sampling [3]. After all, the test results are only as reliable as the samples obtained. So does this mean we will see the demise of current off-line interval based oil testing practice? Is the future of oil testing exclusively in on-line predictive diagnostics?

Off-line oil testing

To answer this question we firstly need to understand the principles behind interval based oil tests for preventative maintenance [2]. These established off-line tests provide virtually all of the information required to determine the condition and operating state of a transformer. They should be performed a minimum of once a year and more frequently for critical transformers. When a fault is detected sampling frequency must be increased to determine the generation rate. In general all of these tests are performed in a laboratory environment as some of the tests require delicate glassware and/or sensitive equipment. However, there are portable dissolved gas analysers and dielectric systems that can be used in the field for urgent situations. The tests can be summarised as follows:

**Dielectric breakdown voltage**

This is a measure of the oil’s ability to withstand voltage stress without failure. Conductive particles and contaminants will lower the breakdown voltage. However, a high dielectric breakdown does not necessarily indicate the absence of contaminants. Different test methods may be employed for routine verification of new oil which is free of contaminants, as opposed to testing oil that has been in service or processed or taken from equipment where there is risk of contamination and therefore sensitivity to contaminants becomes important.

**Acidity**

This test determines the amount of acidic components formed by degradation of the oil. The measure of acidity is given by the neutralization number. The cause of increases in acidity is mostly due to oxidation of the insulation. In the presence of oxygen and high temperatures transformer oil will become more acidic. The neutralization number obtained is used to determine when oil should be reclaimed or replaced.

**Interfacial tension**

This test measures the forces of attraction between oil and water molecules. When oil ages, polar compounds form in the oil. These polar compounds are the precursors to the acidic by products that cause the increase in the acidity of the oil. The IFT and the acidity are linked. In most cases as the IFT decreases the acidity will increase.

![Fig.1: Oil breakdown products](image)

energize - April 2005 - Page 18
Power factor

Also called dissipation factor or dielectric factor, this test measures the power lost or dissipated in the oil when the oil is subjected to an AC electric field. A high power factor value indicates the presence of contaminants in the oil.

Dissolved gas analysis (DGA)

Gases generated in a functioning transformer are used to evaluate the operating status of the equipment and the presence of incipient faults. Corona, overheating and arcing within an oil filled transformer will produce combustible and non-combustible gases. These gases are extracted and analyzed. By comparing the gas concentrations, their ratios and generation rates, the type and severity of a fault can be determined. See Fig. 1.

The process of oxidation can be slowed using oxidation inhibitors that are added to the oil. However, the inhibitor is consumed with time. If it is replenished prior to it being completely depleted, the service life of that oil will be increased.

Furan analysis

A large part of the solid insulation system within a transformer is comprised of the paper that wraps the conductors and pressboard between the winding components. When the paper and pressboard are abused and overheated, the cellulose in them will break down to form glucose and other chemicals. The glucose in turn decomposes into furanic compounds which are released into the oil. See Fig. 2. By monitoring these compounds the condition of the paper can be assessed.

Metals analysis by ICP

In suspect transformers the dissolved gases may indicate a type of fault but not where the fault is located. By measuring the metals found in the oil the location of an incipient fault can be identified.

On-line test systems

On-line test systems are based on dissolved gas analysis. These include fault detector/condition monitors and complete DGA monitors.

In both cases continuous on-line testing offers the possibility of totally eliminating the problems associated with improper oil sampling. In order to fully benefit from this feature it is important to ensure that oil is drawn from and returned to chosen points in the transformer oil circulation circuit so as to ensure representative sampling. It is also important that the oil is suitably conditioned prior to testing to ensure measurement consistency.

Fault detector/condition monitors operate on the principle of measuring one or two key parameters. As has been seen in the DGA test described above, hydrogen is produced in all fault types. Therefore measuring small concentrations of dissolved hydrogen serves as an excellent fault indicator. Similarly moisture is a very useful indicator of overall condition of both oil and solid insulation. These are therefore regarded as key parameters.

Continuous measurement of these parameters lends itself to predictive diagnostic methodology in the form of Intelligent electronics which can log, trend, identify and diagnose the development of abnormalities at an early stage of development. Morgan Schaffer Systems' Calisto dissolved hydrogen and moisture monitor is one of these detector/condition monitors. Fig. 3 illustrates a typical installation. It is designed to be a practical, reliable and robust predictive diagnostic tool capable of operating in extreme environments without calibration complications, at moderate cost. The oil is continuously circulated and conditioned with its own pump and in-built conditioning system. Alarms can be triggered long before the transformer is tripped by a Buchholz relay, which is typically too late since the damage has been done.
Tuned to harmony

The implementation of South Africa’s Demand Side Management (DSM) program requires close co-operation of all parties involved. Eskom, energy service companies (Esco’s), municipalities, technology suppliers, measurement and verification bodies, consumers and others play the role assigned to them, as do the components of the ripple control system.

Farad and Enermet make sure that load controllers, transmitters, coupling units and receivers interact harmoniously to the benefit of South Africa’s electricity supply. We guarantee not only the function of each component but the performance of the entire system. This has been our business since 1956 – and we stick to it.

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Complete DGA monitors on the other hand offer the advantage of a full analysis and would seem to offer the ideal solution. Unfortunately they are very costly and suffer from maintenance and calibration issues. They are therefore not regarded as practical predictive diagnostic tools for general application, but do find use in the most urgent and critical situations.

Comparison of test methods

Interval based oil tests for preventative maintenance offer the advantages of presenting a complete picture of the condition and operating status of a transformer, provided sampling is sound. But there is significant risk of not detecting rapidly developing faults. Cost is low at normal test frequency.

Continuous on-line complete DGA oil testing will give an excellent picture of the condition and operating status of a transformer. The risk of improper sampling is eliminated and it will give early detection of rapidly developing faults. However there are maintenance and calibration complications and cost is very high.

Continuous on-line fault detection/condition monitoring with predictive diagnostics based on hydrogen and moisture monitoring poses no risk of improper sampling and will give early detection of rapidly developing faults, as well as a good indication of overall oil and solid insulation condition. Cost is moderate, reliability high and application straightforward.

Neither of the above on-line methods offers the complete scope of oil tests. They therefore lack those aspects of the diagnostic capability embodied in the additional tests. Should either detect onset of a defect it would be normal practice to conduct a complete off-line oil test in order to permit a more comprehensive diagnosis.

Conclusion

Transformer oil testing is firmly entrenched in both preventative maintenance and predictive diagnostics methodologies. This situation is unlikely to change in the foreseeable future.

Traditional periodic preventative maintenance oil testing will always have its place for reasons of lower cost and more comprehensive diagnostics capability.

Continuous on-line fault detector/condition monitors will find application on critical units where the cost of faults not detected by traditional methods exceeds the moderate cost of the monitors.

Continuous on-line complete DGA oil testing systems will only find application in the most extreme situations where cost of failure is exceptionally high.

References

