Advanced diagnostics provide a complete health check for power transformers

Power transformers are mission-critical elements in many industrial, utility and power generation installations. Should an unexpected failure occur then it can result in a lengthy downtime, with consequent loss of operating revenue, and expensive repairs. Planned maintenance is the best insurance against transformer failure and that’s where advanced diagnostic techniques come in. They offer an efficient, cost-effective way of assessing the overall condition of a transformer fleet so that areas of potential concern can be flagged and action taken well before a potential failure develops into a serious fault.

Furthermore, if an operator has a transformer that is already causing concern, then diagnostic tests can establish the severity of the problem, locate the fault and help the service team to provide expert advice on what action to take. For example, with regular testing it might be possible for the transformer to continue in service, while operating under a safe, reduced load, until a planned service interval is reached.

ABB’s transformer diagnostic service utilizes four main techniques – SFRA (Sweep Frequency Response Analysis), FDS (Frequency Domain Spectroscopy), winding resistance measurement and oil sampling.

SFRA

The SFRA (Sweep Frequency Response Analysis) test, carried out by a Pax FRAX-101 system, is an important tool for identifying potential winding geometry changes. It consists of a low-voltage, off-line, measurement of the impedance of the transformer windings as a function of frequency. The test is performed by injecting a variable frequency AC voltage into each individual transformer winding and plotting the responding current as a curve.

We recommend that SFRA reference curves should be captured in the factory to provide a baseline ‘finger print’ of the windings in an as-new condition. However, for installed transformers, a field test can provide the baseline curves. SFRA testing should be performed periodically during the service life of the transformer, or after a specific incident that has caused significant fault currents. An alternative approach is to utilize a type-based comparison between sister transformers with the same design. Under certain conditions, a construction based comparison can be used when comparing measurements between windings in the same transformer.

When interpreted by an expert, comparison of the SFRA test with the transformer’s original baseline curves is an excellent method to check for movement or displacement of windings or winding circuits that could affect its ability to withstand faults. It is much more definitive than low-voltage impedance tests routinely performed on transformers, it helps avoid catastrophic failures and can even locate the exact position of a fault.

Figure 1 shows a typical SFRA analysis in which the pronounced dip in the frequency response curve of one of the transformer phases indicates a potential fault – most probably due either to a winding failure or core movement.
FDS

FDS (Frequency Domain Spectroscopy), carried out by a Pax IDAX-206 system, is used to assess the integrity of a transformer's insulation system. The test determines the volume of moisture and presence of contaminants in the solid insulation, as well as the conductivity and power factor of the oil. This is an extremely useful tool in an overall condition assessment programme as standard power factor tests alone do not yield this type of information.

The FDS test measures the dielectric properties (capacitance, loss and power factor) of the transformer's insulation as a function of frequency. This off-line test utilizes the same type of connections as a standard (Doble) mains frequency insulation power factor test. However, by covering a much wider frequency range – typically 1 mHz to 1000 Hz – the test offers increased sensitivity to insulation issues.

An important primary use of the FDS test is to determine the moisture content of the cellulose insulation structure of power transformers. It is difficult to obtain a reliable assessment of moisture content by oil sample tests, as the water is transferred between the solid insulation and the oil as the temperature changes. An oil sample has to be taken at relatively high temperatures, when the transformer is in equilibrium. But this is a relatively rare state for a transformer and can result in unreliable assessments.

A perfect illustration of the advantages of FDS is provided by an exercise in which a customer provided ABB with a list of seven suspect transformers. In each case, moisture in oil test results had indicated the need for oil processing and drying. By carrying out FDS tests we were able to show that only two units actually needed drying. So our recommendation was to dry these two, while keeping the other five under careful surveillance. The customer not only made a very significant saving in operational and maintenance costs, preventing unnecessary drying operations on five transformers also reduced the risk of over-drying and loosening of windings.

Winding resistance measurement

Winding resistance measurement tests are carried out by an Omicron CPC 100 system. This is used to inject a DC current of up to 2kV through the transformer windings and it then measures the voltage drop across that winding - enabling the resistance to be calculated.

The main purpose of this test is to check for significant differences between the windings, which could indicate field damage or deterioration, and also to ensure that the transformer connections are correct and that there are no severe mismatches or open circuits.

Oil sampling

Just as a blood test can provide a doctor with a wealth of information about their patient, a sample of transformer oil can tell an engineer a great deal about the condition of a transformer, enabling them to effectively manage the asset for extended life and enhanced reliability.

The role of the oil in the transformer is to both cool it and insulate the internal components, and in doing so it bathes every internal component. As a result, the oil contains around 70 per cent of the available diagnostic information for the transformer and laboratory analysis can provide an early indication of a developing condition such as tap changer arcing.

We recommend that the best information can be obtained from oil sampling by viewing trends. So it is useful to take a bench-mark sample when a transformer has been energized or an oil treatment performed and to then take further samples at regular intervals so that any variation in quality can be measured in order to monitor developing faults.

Typical tests carried out in the laboratory analysis of the oil sample include:
- Breakdown voltage (dielectric strength)
- Moisture content
- Dissolved gas analysis (DGA)
- Oxidation

Each of these parameters impacts on the other parameters, and they all work together to affect the condition of the transformer.

Summary

In general, power transformers are very reliable devices and will provide excellent service for many years if maintained and serviced regularly. Failures, when they occur, are usually very serious and require costly repairs and inconvenient downtime. The best insurance against failure is a planned monitoring and testing regime. The new generation of high-technology, non-invasive, diagnostic techniques can play a vital role in this regime.

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