Insight: Transformer Monitoring and Testing

A Key Component to Understanding Transformer Health

Recognizing the Risk

Large Power Transformers (LPTs) are a critical part of the electrical grid. Depending on the system configuration the loss of a single transformer can have a significant impact. The rewind or replacement of a failed LPT can take 1-2 years or longer, depending on the global constraints. LPTs are also one of the most expensive pieces of equipment in an electrical substation. Considering these two reasons alone it is in the utility's best interest to perform the appropriate monitoring and testing since that can help identify potential concerns before a catastrophic event occurs.

Dissolved Gas Analysis

Dissolved gas analysis (DGA) is a method of testing transformer fluid to determine the overall health of a transformer. DGA has been used for many years and is the most important maintenance practice for liquid-immersed transformers. Over the years, as more data is collected and new technologies emerge, the interpretation of DGA has become very reliable. In most cases, DGA samples can be collected while the transformer is in service as opposed to other testing that requires the transformer to be out of service.

LPTs contain a fluid for the purpose of electrical insulation and heat transfer. Typically, the fluid used is mineral oil, but other fluids such as synthetic esters are also being used. As the insulating materials within a transformer break down from aging or electrical faults, gases are released into the transformer fluid. By measuring and trending these gas concentrations, it is possible to narrow down what is happening inside the transformer e.g. whether there is normal wear and tear or a problem such as an internal electrical fault. Also depending on the type of gas generated and the rate that it is generated, testing results can provide information to help determine the severity of an issue. Having this information can allow time to schedule a thorough inspection and take appropriate actions before a trip or a catastrophic event occurs.

Critical Gasses measured by DGA

Depending on the types of gases seen and the rate of increase, the severity of an electrical fault can be determined. As a fault develops, temperature increases and corresponding gases are generated. For a typical DGA sample, there are 9 gases that are measured.

- Oxygen – Typically an indication of air ingress and therefore a leak to the atmosphere may be present.
- Nitrogen – Typically an indication of air ingress and therefore a leak to the atmosphere may be present. For sealed transformers with a nitrogen blanket, a higher concentration may be seen.
- Hydrogen – Low energy event that has possible partial discharge activity and/or overheating of fluid.
- Methane – Low energy event that has possible partial discharge activity and/or overheating of fluid.
- Ethane – Overheating of oil.
- Ethylene – Overheating of oil associated with higher temperature overheating.
- Carbon Monoxide – Overheating of paper insulation.
- Carbon Dioxide – Overheating of paper insulation.
- Acetylene – Arcing in oil with very high temperature, overheating of oil. Acetylene is generated by arcing and therefore an internal fault is most likely present. Even a very low concentration of acetylene can indicate a severe problem.

Analyzing individual gas concentrations on their own is only one step in understanding DGA. A single gas concentration that is higher than industry standards should be considered a warning but may not indicate a serious problem based on the history of the transformer. Additional DGA samples are needed to verify an increasing trend and other test methods may be necessary.

Gassing Trends

It is important to perform routine DGA to establish trends and rate increases of these critical gases. This is important because a significant increase in a key gas may be a concern even though the gas concentration does not exceed the industry standards for that specific sample.

IEEE Std C57.104 Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers and IEEE Std C57.155 Guide for Interpretation of Gases Generated in Natural Ester and Synthetic Ester-Immersed Transformer are the industry standards that should be used. These standards provide the acceptable limits of individual gasses along with the acceptable rate of change.

Oil Quality, Furan Analysis and Corrosive Sulfur Testing

Additional oil tests include oil quality, furan analysis, and corrosive sulfur testing.

- Oil quality is a good indicator of fluid health and measures Dielectric Strength, Power Factor, Moisture, Color, Interfacial Tension and Acidity. As oil ages and breaks down these parameters will determine if the fluid should be reconditioned.
- Furan Analysis indicates the degree of degradation of the transformer paper insulation. As a transformer ages the paper insulation breaks down. If the paper degrades enough it is possible to experience turn-to-turn shorts and eventually complete failure.
- Corrosive sulfur that is present in transformer oil can cause deposits of an electrically conductive compound which could lead to electrical faults within the transformer.

Offline Electrical Testing

Routine outages are required to remove the transformer from service and perform offline testing.

- Transformer Power Factor
- Bushing Power Factor and Capacitance
- Transformer Turns Ratio (TTR)
- Insulation Resistance
- Impedance
- Sweep Frequency Response Analysis (SFRA)

Online Monitoring

Continuous online monitoring has become more common, especially for critical LPT’s. With new technologies it is now possible to equip transformers with online monitors that provide an even better understanding of a transformer’s health. This real-time data can be used to make quick informed decisions. Online monitoring can come in many different levels of monitoring from one single parameter to multiple parameters that populate a sophisticated condition monitoring software platform that uses algorithms to determine overall health.

Bushing monitoring, DGA, and partial discharge are a few of the options that utilities are using as part of their online monitoring program. Monitors can be retrofitted onto existing transformers or supplied as part of a new transformer installation.

However, just like the other testing methods that have been discussed, the data gathered needs to be reviewed by a qualified individual and actions taken if deemed necessary.

While online monitoring provides real-time data this should not take the place of the other testing and monitoring that is already being performed.

Recommendations

Since not all transformers are as critical as others, it is up to the utility or the LPT owner to develop a monitoring and testing program that best suits their needs. DGA, oil quality, furan testing, and offline testing must be performed at a minimum. Online monitoring provides a great deal of data that can be used to make informed decisions in a relatively quick timeframe and therefore should be considered, especially for critical LPTs.

Resources / Standards

IEEE Std C57.104 Guide for Interpretation of Gases Generated in Mineral Oil-Immersed Transformers

IEEE Std C57.155 Guide for Interpretation of Gases Generated in Natural Ester and Synthetic Ester-Immersed Transformers

NFPA* 70B Chapter 11 – Testing and Test Methods

*While NFPA documents are the global standard used by AIG, international equivalents may be acceptable.

For more information, contact your local AIG Risk Engineer.