DELTA-X RESEARCH

Bringing science to risk management

Major Utility Implements Innovative Approach to Transformer Health Assessment

with Reliability-based Dissolved Gas Analysis

One of the largest U.S. electric power utility companies, with nearly 50,000 megawatts of generating capacity, over 36,000 miles of high-voltage distribution lines, and over 7 million retail electricity customers, has an electric power network that includes close to 6,500 high-voltage transformers.

The company spends substantial time and resources to ensure that those transformers are maintained in ideal condition to provide a high level of service to their customers.

But, like utilities around the globe, this utility is facing a significant challenge when it comes to keeping their transformer fleets up and running, because of a change in transformer manufacturing that happened 30 years ago.

A Challenge to Transformer Reliability

Transformers designed before the 1980s were robustly built, using large internal clearances and generous amounts of copper and steel, with average service lifetimes of over 50 years. But since the late 1980s, computer-aided design and advanced manufacturing methods have made it possible to economize on expensive materials and reduce overall size, resulting in lighter-weight, more compact transformers that have an average service lifetime closer to 30 years.

Utilities are only now reaching the point where the first wave of the lighter-weight transformers is starting to fail, at the same time as a wave of older transformers that were built 50 years ago. For the next 20 years, there will be a steep increase in the number of transformers reaching end of life, until most transformers in service have a similar 30-year lifespan.

"We're approaching a nexus between the two generations," explained Nicole Kurant, a Lead Engineer for Asset Management System Intelligence. "Across the industry, high-voltage transformers are nearing end-of-life at the same time, and if we aren't proactive, this could result in excessive disruptions and/or unplanned significant capital expenditures through a perfect storm of increased failure rates and a limited supply of new transformers."

With transformer build times averaging two years and prices for copper and specially-treated steel rising, electric power providers must take steps to keep existing transformers operating safely and reliably for as long as possible.

Testing and Health Assessment

Just like people, large transformers need periodic health checkups and tests that help with the early detection and diagnosis of any problems that may be developing. The prevailing method for screening and routine health assessment of transformers is sampling and analysis of the insulating oil.

One of the most important oil tests is dissolved gas analysis (DGA), which detects trace concentrations of gases created by a heat generating fault inside a transformer. Interpreting patterns of fault gas concentrations can detect and identify problems, even at an early stage. Conventional methods of DGA interpretation are handed down from the dawys of slide rules, using common sense rules and simple statistical limits. Although conventional DGA is effective enough to be widely used in the industry, it has known weaknesses, including producing significant numbers of errors, both those that indicate a problem where one does not actually exist (false positives) and those that miss existing issues (false negatives).

Many transformers are erroneously classified as problematic, while others have serious problems that are passed over or misdiagnosed. Consequently, time and resources are wasted on unnecessary investigation of false positives or false alarms, and in the case of false negatives, an unexpected failure can trigger costly power outages or catastrophic damage. The utility wanted to find a way to reduce these issues.

Reliability-based DGA

Seeking to improve its system for transformer health assessment, the utility investigated advanced computer-based methods for interpreting dissolved gas analysis (DGA) test data. One approach was Reliability-based DGA, developed by Delta-X Research of Victoria, BC, Canada.

Chemical thermodynamics is applied to convert the fault gas concentrations into a fault energy index, which provides a simple measure of how much energy is expended by an internal fault. The more energy expended by a fault, the greater the severity of the fault.

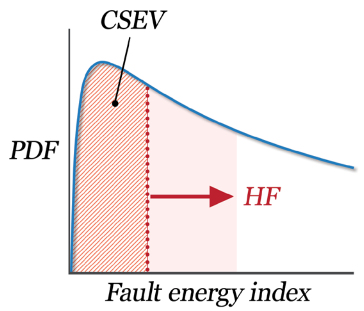

Figure 1: Failure probability density function curve, providing cumulative severity of transformer gassing history (CSEV) and hazard factor (HF), the rate at which the probability of failure is increasing.

With fault energy index as a key metric, Reliability-based DGA applies advanced statistics to large data sets of transformer DGA histories and DGA-related transformer failures to create a model that indicates the probability of a failure as the fault energy index increases. (While common sense might suggest that there is a simple linear relationship between the fault energy index increasing and the probability of a failure, this is not actually the case – Figure 1 shows how the fault energy index value just before failure is distributed.)

Reliability-based DGA then uses the failure model to evaluate the severity of a particular transformer's gassing history and to predict the likelihood of near-term failure. In short, Reliability-based DGA correlates fault gas production with transformer failures and provides a way for owners to assess the state of their transformers. With a clear understanding of their transformer fleet, owners can prioritize maintenance and asset replacements, making better operational and financial decisions with confidence.

The utility evaluated the Reliability-based DGA method by applying it to existing DGA data for 7,280 transformers, including the nearly 6,500 currently in service. Engineers compared the results obtained by Reliability-based DGA versus the results obtained by conventional DGA (Figure 2).

Transformer fleet	7,280	100%
Conventional DGA	1,785	24.5%
Reliability-based DGA	1,729	23.8%
Conventional or R-DGA	2,783	38.2%
Conventional and R-DGA	731	10.0%
Conventional not R-DGA	1,054	14.5%
R-DGA not conventional	998	13.7%

Figure 2: Comparison, conventional DGA and Reliability-based DGA. Of the 1,054 identified by conventional DGA only, most were false alarms. Of the 996 identified by R-DGA only, most were issues missed by conventional DGA.

Of the 1,054 cases where conventional DGA indicated a problem and Reliability-based DGA did not, it was determined that almost all were false alarms. Of the 998 cases identified as problematic by Reliability-based DGA but not by conventional DGA, most were considered by the engineers to represent real problems that had been missed by conventional DGA. Sixty-eight of those cases were investigated in detail, and 63 were confirmed as at-risk transformers; two were explained by bad data; and in three cases no actual transformer problem existed.

The results were in: Reliability-based DGA was vastly superior to conventional DGA in largely avoiding both false positives and false negatives – so the utility could save money by better targeting their maintenance efforts and increase reliability by finding problems that would otherwise have remained hidden.

Major Utility Adopts Reliability-based DGA

Because of the radically superior performance of Reliability-based DGA, the utility adopted it immediately as a key component of its Transformer Health Surveillance process.

"Reliability-based DGA is one of the tools we're using to effectively triage and prioritize our transformer maintenance, and to get all we can out of our transformer fleet," said Ms. Kurant.

"We've built our analysis criteria around Reliability-based DGA to help assess our fleet, which gives us the ability to identify and focus on at-risk transformers, so we can implement an effective strategy to replace them as and when needed, in an organized and controlled manner."

With their embrace of this new and improved transformer health analysis tool, this large utility continues to demonstrate their dedication to maintaining the reliability and affordability of energy for the customers and communities they serve.

Bringing science to transformer risk management™

Since 1992, Delta-X Research has invested in the research and development of advanced analytics for assessing the health of high-voltage equipment. Generation, transmission and distribution utilities around the world, as well as leading industrial operations, rely on Delta-X Research to provide key decision support tools for managing their critical assets.

With over half of the largest utilities in the USA as TOA4 subscribers, you join a large community whose combined experience over two decades has been applied to create the most effective and recognized diagnostic tool for assessing and tracking the condition of high-voltage electrical apparatus. With TOA4, you are in good company.

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