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새로운 방식의 변압기

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Components of a Comprehensive Transformer Monitoring and Diagnostic System

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1. Abstract

A wide range of data is available as too causes of large power transformers. Although the percentage of transformer component failure rates vary, all data shows that the top three failure mechanisms are Load Tap Changers (LTC), Bushings and Windings. To date, the most common methods employed to determine the health of a transformer are off line tests and online temperature monitoring, winding hotspot calculations and dissolved gas analysis.

2. Introduction

Introduction Use of periodic offline tests can narrow, but not eliminate the uncertainty in failure prediction. These tests will only identify if there is a “fatal” flaw and failure is imminent. If these tests show the transformer to be in “good health”, all it really means is that there is no clue as to when the transformer will fail, except that failure does not appear to imminent.

2.1 A Comprehensive Transformer Monitoring and Diagnostic System

To determine what should be used in a comprehensive transformer monitoring and diagnostic system (TMDS), one usually considers the failure history of their transformer fleet as a guideline. Table 1 shows data based on seven years of transformer failures. This data is complied from various sources from Doble Engineering Company. With a properly designed TMDS system, problem detection rates of at least 60% are easily achievable.

component	%	Diagnostic Elements
Winding	43	DGA, Moisture in Oil,Oil Dielectric, Leakage Reactance, Winding Hot Spot, partial discharge, acoustic signature analysis for loose windings
Bushing	19	Power factor, capacitance, partial discharge
LTC	16	Temperature differential, partial discharge, DGA, operation counter, I^2T, control and motor monitoring, vibration signature, automatic reversing switch cleaning
Tank and Oil	8	Nitrogen System, Bladder health, moisture in oil, oil dielectric
Core	4	DGA, partial discharge
Other	10	Cooling system health, Ageing, Dynamic rating

2.2 Components of a TDMS System

Temperature Monitoring, Calculated Winding Hotspot and Direct Winding Hot Spot Measurements Historically, temperature monitoring of transformers was performed sing top oil temperature combined with an a simulated winding hot spot. The accuracy of such devices were often suspect. With every increase of 6℃ in winding temperature results in a loss of life of 50%. With the additional of electronics, many systems offer the capability to more accurately calculate the winding out spot. Improving the accuracy of such measurements allows the sure to mange loading on the transformer. Yet a more accurate method of monitoring winding hot spot is to embed fiber optic temperature probes directly at the hot spot location. This system will provide a direct measurement of the hot spot.

2.2.1 Dynamic Transformer Rating

Temperature limits on transformers are based on a all fans and pumps, running, a specific ambient and the transformer being in lossest tap. By combining current ambient temperature, health of the cooling system, existing tap and more accurate winding hot spot, the dynamic thermal rating can be monitored. Experience has shown the transformers can be loaded 1-0-20% higher than their “static” or design rating when real time information is available. This information becomes especially critical during system contingencies.

2.2.2 Cooling System Monitoring and Control

Basic systems typically watch for increases in system loading and turn on cooling when the system loading reaches a certain percentage of the transformer nameplate. More advanced systems predict where the top oil and winding temperatures are headed (based on present temperatures, loading and tap position). If the predicted temperatures exceed the traditional temperature set points, the cooling is turned on immediately. By turning the cooling system on early, it is possible to pre-cool the transformer and avoid excessive insulation aging and will reserve more overload capacity for later in the day. Features should include fail Safe operation, Fan/pump current, Automatic self testing, and duty cycling.

2.2.3 LTC Monitoring and Control

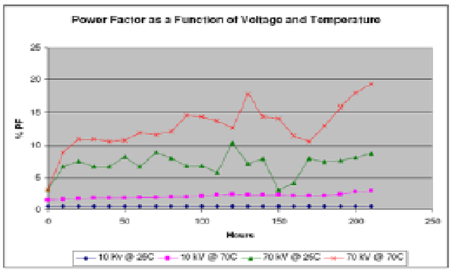
Due to the number of moving parts, tap changer operation can be one of the more important functions to monitor on a transformer. Historically, the majority of the focus on an LTC has been placed on the high voltage components, i.e. the tap changer contacts and insulating oil. While the importance of monitoring the high voltage components cannot be underestimated, on-line condition monitoring for an LTC needs to start with the tap changer controls and drive mechanism. Combining monitoring and control into a single device allows the control system to monitor itself. Other itms to consider include temperature differential between the LTC and main tank, vibration signatures, motor current signature, control, hunting and automatic passing trough neutral to clean reversing switch.

2.2.4 Gas and Oil Monitors

The monitoring of dissolved gases in transformer oil is probably the most well known of all forms of condition monitoring for substation equipment. Every modern utility in the world employs some form of dissolved gas analysis on its transformer fleet. The wealth of information that can be provided by gas in oil analysis make it the single most important element in any transformer maintenance program. As shown in the Doble failure data, winding related failures have been the single largest source of transformer failures. Gas in oil monitoring has been the most common method used to detect failures of this type. Since transformer failures can occur rapidly, on-line gas monitoring is included in most transformer monitoring systems. Both Key Gas and Multi-Gas monitors are available on the market today. Maintaining proper moisture levels is critical to maintaining a healthy transformer. The presence of excessive moisture in transformer insulation can lead to premature failures through, partial discharge activity, bubble generation and lower dielectric strength The presence of excessive moisture also accelerates the degradation process of cellulose thereby prematurely aging the transformer's insulation system resulting in shorter transformer life expectancies.

2.2.5 Bushing Monitoring

In most transformer failure studies, bushing failures are one of the more predominant failure modes. Moisture ingress, oil deterioration, paper aging and overheating all lead to degradation of bushing insulation. As the dielectric insulation breaks down, partial discharges occur further damaging the bushing insulation through treeing or puncturing of the paper layers. These changes in the quality of the bushing insulation frequently result in changes in the bushing power factor and capacitance readings which are easily measured on line in bushings fitted with test (potential) taps.
The effectiveness of periodic bushing power factor and capacitance measurements at accurately identifying bushing degradation has been documented in Doble papers and other industry conferences over the past few decades. While most utilities recognize the effect temperature has on these readings, the affect increased voltage stress has on the ability to detect potential problems is not as well known. The figure on the right shows power factor measurements performed on a known defective bushing at various temperatures and voltages. As shown below, performing these measurements on-line at transformer operating voltages and temperatures can greatly improve the ability to detect potential problems early.



2.2.6 Winding Reactance

Leakage reactance measurements can provide important information on the overall health of transformer windings. While most IED's and on-line sensors monitor the transformers "electrical" health, on-line leakage reactance measurements will provide the opportunity to monitor the "mechanical" health of the transformer. Leakage reactance measurements are generally performed during offline testing to monitor for deformation of the transformer windings.

2.2.7 Partial Discharge

Partial discharges may occur due to temporary over-voltage conditions or transients, insulation degradation due to aging, moisture, contamination or loss of insulating fluid and areas of high dielectric stress due to flaws or defects introduced during the manufacturing process or field repairs. The primary causes of PD in transformers are stray flux, bad contacts/floating potentials, voids in solid insulation and creeping/tracking discharges in cellulose insulation. Since some level of PD is normal in any transformer, the best way to monitor PD is through a continuous on-line monitor. Continuous monitoring allows the ability to track partial discharge activity and correlate its occurrence with load and temperature. PD activity may be dependent on load, temperature, LTC position or other conditions. By correlating the PD activity with operating data, loading guidelines may be instituted to limit PD activity to reduce or eliminate insulation breakdown. Implementing loading guidelines may be more tolerable than rewinding transformers when the source of the PD is deep with the transformer windings.

3. Conclusions

The time to failure for transformers can be unpredictable. Fortunately, most transformers will provide an identifiable sign of an impending failure in the days or weeks prior to the failure. On-line monitoring offers the best opportunity to prevent these failures by identifying transformer problems early. While there are a wide variety of monitoring devices available in the marketplace today, the data provided by these discrete sensors and IED's can be greatly enhanced when correlated with loading, temperatures and other critical information.
Comprehensive transformer monitoring and diagnostic systems offer the best opportunity to capture and consolidate these signals to provide asset managers the timely, accurate and meaningful information they require to prevent failures by identifying transformer problems early.

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