ON-LINE MONITORING SYSTEM FOR POWER TRANSFORMERS

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Abstract: *Power transformers are the most important and expensive equipment from the electricity transmission system,* so *it is very important to know the real state of health of such equipment in every moment. De-energizing the power transformer accidentally due to internal defects can generate high costs. Annual maintenance proved to be ineffective in many cases to determine the internal condition of the equipment degradation due to faults rapidly evolving. An On-line Monitoring System for Power Transformers help real-time condition assessment and to detect errors early enough to take action to eliminate or minimize them. After abnormality detected, it is still important to perform full diagnostic tests to determine the exact condition of the equipment. On-line monitoring systems can help increase the level of availability and reliability of power transformers and lower costs of accidental interruption. This paper presents* ***cases studies*** *on several power transformers equipped with on-line monitoring systems from Transelectrica substation.*

1. INTRODUCTION

A sudden increase in key gases and the rate of gas production is more important in evaluating a transformer than the accumulated amount of gas. One very important consideration is acetylene (C_2H_2). Generation of any amount of this gas above a few ppm indicates high-energy arcing. Trace amounts (a few ppm) can be generated by a very hot thermal fault (500 degrees Celsius or higher). A one- time arc, caused by a nearby lightning strike or a high voltage surge, can also generate a small amount of C_2H_2. If C_2H_2 is found in the transformer ,oil samples should be taken weekly or even daily to determine if additional C_2H_2 is being generated.

If no additional acetylene is found and the level is below the minimum value established by the standards, the transformer may continue it’s service. However, if acetylene continues to increase, the transformer has an active high-energy internal arc and should be taken out of service immediately. Further operation is extremely hazardous and may result in explosive catastrophic failure of the tank, spreading flaming oil over a large area.

2. TRANSFORMER OIL TESTS THAT SHOULD BE PERFORMED ANNUALLY WITH DISSOLVED GAS ANALYSIS

Dielectric Strength. This test measures the voltage at which the oil electrically breaks down. The test gives an indication of the amount of contaminants (water and oxidation particles) in the oil, [1].

The dielectric strength test is not extremely conclusive; moisture in combination with oxygen and heat will destroy cellulose insulation long before the dielectric strength of the oil has indicated anything is going wrong but the tests explained below are much more important in that regard.

Interfacial Tension. This *Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method*, is used by laboratories to determine the interfacial tension between the oil sample and distilled water. The oil sample is placed in a beaker of distilled water at a temperature of 25 degree celsius. The oil will float. because it's specific gravity is less than that of water. There should be a distinct line between the two liquids. The interfacial tension number is the amount of force (dynes) required to pull a small wire ring upward a distance of 1 centimeter through the water/oil interface. A dyne is a small unit of force equal to 0.000002248 pound. Good clean oil will make a very distinct line on top of the water and give an IFT(interfacial tension) number of 40 to 50 dynes per centimeter of travel of the wire ring, [2].

As oil ages, it is contaminated by tiny particles (oxidation products) of the oil and paper insulation. Particles on top of the water extend across the water/oil interface line which weakens the surface tension between the two liquids. Particles in oil weaken interfacial tension and lower the IFT number.

IFT and acid number together are excellent indictors of when oil needs to be reclaimed. It is recommended the oil be reclaimed when the IFT number falls to 25 dynes per centimeter. At this level, the oil is very contaminated and must be reclaimed to prevent sludging, which begins at around 21 dynes per centimete. If oil is not reclaimed sludge will settle on windings, insulation, cooling surfaces, etc., and cause loading and cooling problems. This will greatly shorten transformer life.

There is a definite relation between acid number, the IFT, and years-in-service. The accompanying curve, *figure 1* shows the relationship and is found in many publications. Notice that the curve shows the normal service limits both for the IFT and the acid number, [3].

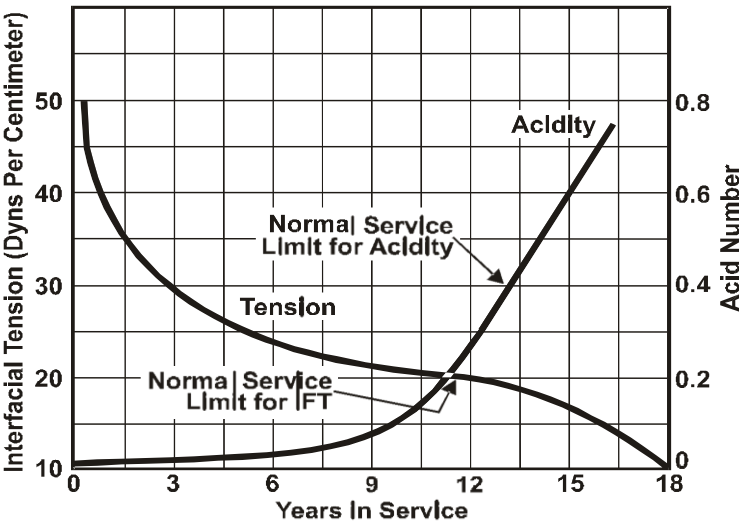

Fig.1. Service Limits for Transformer Oil.

Acid Number. Acid number is the amount of potassium hydroxide (KOH) in milligrams (mg) that it takes to neutralize the acid in 1 gram of transformer oil. The higher the acid number, the more acid is in the oil. New transformer oils contain practically no acid. Oxidation of insulation and oils form acids as the transformer ages. Oxidation products form sludge particles in suspension in the oil which dripping inside the transformer. The acids attack the metals inside the tank and form soaps. Acid also attacks cellulose and accelerates insulation degradation. Sludging has been found to begin when the acid number reaches 0.40. The oil with this acid number should be reclaimed long before it reaches 0.40. It is recommended that the oil be reclaimed when the acid number reaches 0.20 mg KOH/g, [3].

Furans. Furans are a family of organic compounds which are formed by degradation of paper insulation. Overheating, oxidation, acids, and decay caused by high moisture with oxygen accelerate the destruction of insulation and form furanic compounds.

When furans become greater than 250 parts per billion (ppb), [4], the oil should be reclaimed; paper insulation is being deteriorated and transformer life is reduced at a high rate. Furanic content in the oil is especially helpful in estimating remaining life in the paper insulation, particularly if several prior tests can be compared and trends established.

Oxygen. Oxygen (O_2) must be watched closely during the tests. Many experts and organizations, believe that above 2,000 ppm, [3], oxygen in the oil greatly accelerates paper deterioration. This becomes even more critical with moisture above safe levels.

High atmospheric gases (O_2 and nitrogen [N_2]) normally mean that a leak has developed in the bladder or diaphragm in the conservator. If there is no conservator and pressurized nitrogen is on top of the oil, expect to see high nitrogen but not high oxygen.

Oil Power Factor. Power factor indicates the dielectric loss (leakage current associated with watts loss) of the oil.A high power factor indicates deterioration or contamination from byproducts such as water, carbon, or other conducting particles, including metal soaps caused by acids attacking transformer metals, and products of oxidation. If the power factor is greater than 1.0% at 25 degrees celsius, [4], the oil may cause failure of the transformer; replacement or reclaiming of the oil is required immediately. Above 2%, oil should be removed from service and replaced because equipment failure is imminent, [5]. The oil cannot be reclaimed.

Moisture. Moisture, especially in the presence of oxygen, is extremely hazardous to transformer insulation.

When 2% moisture is reached, plans should be made for a dry out. Never allow the moisture to go above 2.5% in the paper or 30% oil saturation before drying out the transformer, [2]. Each time the moisture is doubled in a transformer, the life of the insulation is cut by one-half as the life of the transformer is determinated by the life of the paper, and the life of the paper is extended by keeping out moisture and oxygen.

When the transformer is new, this water is distributed equally through the transformer but when the transformer is energized, water begins to migrate to the coolest part of the transformer and the site of the greatest electrical stress. This location is normally the insulation in the lower one-third of the winding. Paper insulation has a much greater affinity for water than oil does. Insulation acts just like blotting paper or paper towels; it soaks up water superbly. The water will distribute itself unequally, with much more water being in the paper than in the oil. The paper will even partially dry the oil by absorbing water from the oil, [6]. Temperature is also a big factor in how the water distributes itself between the oil and the paper.

It is critical for life extension to keep transformers as dry and as free of oxygen as possible. Moisture and oxygen cause paper insulation to decay much faster than normal and to form acids, metal soaps, sludge, and more moisture. Sludge settles on windings and inside the structure, causing transformer cooling to be less efficient, and slowly, over time temperature rises. Acids cause an increase in the rate of decay, which in turn forms additional acid, sludge, and moisture at a faster rate. This is a vicious cycle of increasing speed with deterioration forming more acid and causing more decay. The answer is to keep the transformer as dry as possible and free of oxygen as possible.

3.TRANSFORMER DIAGNOSTICS AND REHABILITATION

Determining transformer condition is useful in itself for making short-term decisions regarding operation and maintenance. Assessing transformer condition through diagnostic techniques is also important for conducting asset management studies for transformer replacement. Transformer condition is an important input to an engineering and economic model used in determining the most cost-effective alternative for power train rehabilitation, (continued operation, refurbishment, or replacement). A methodology has been developed to use information derived from the diagnostics described in this document for rehabilitation purposes.

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