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Transformer Diagnosis Using UV-Spectrophotometer

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Abstract - A power transformer is most significant and extremely important element in the power utility industry. Transformers are key-stone in transmission and distribution system. The failure of power transformer causes the interruption of power supply, huge financial loss. Failure coming without warning is responsible for large economic losses and unscheduled outage. In the absence of transformers components monitoring and diagnostics, the failure risk always remain high. The System abnormalities such as over loading, frequent switching, sever weather condition and poor maintains normally contribute to accelerated aging. The lack of proper monitoring and diagnostics leads to high risk of failure.

Diagnostics and proper monitoring plays key role in the life expectancy of proper transformer. Mineral oil in transformer is the inseparable component of the dielectric insulation system. In this paper a new diagnostic technique for power transformer diagnostics known as uv spectrophotometry for transformer oil analysis has been discussed. This paper presents basic information about uv spectrophotometer, sampling and testing of transformer oil. Based on the spectrophotometer results and their subsequent analysis condition of transformer oil can be predicted

Keywords: *Transformer, aging, oil, uv-spectrophotometry, basic information, absorbance, wavelength*

I. INTRODUCTION

A power transformer is most significant and extremely important element in the utility industry. Transformers are key-stone in transmission and distribution system.. The failure of one transformer may cause significant effect for electrical utilities. In electrical energy market due to competition require enhanced system reliability due to periodic diagnostic to avoid sudden failure and losses due to outage duration. Failure coming without warning which is responsible for large economic losses and large outage. In the absence of critical components monitoring and diagnostics, the failure risk always remain high.

When peak load demand increases there is increase in hot spot temperature. Higher hot spot temperature means reduction in assets life and reliability. System abnormalities such as loading, switching, ambient condition and poor maintains normally contribute to accelerated aging. In the absence of proper monitoring and diagnostics, the failure risk always remains high [2].

Diagnostics and proper monitoring plays key role in the life expectancy of proper transformer. Mineral oil in transformer is the inseparable component of the dielectric insulation system. The various contamination levels in oil can be examined and verified using UV spectrophotometry. UV

Spectrum analyse the impurities in transformer oil with respect to contamination present in it and interpret dielectric response of insulation system and also analyse impurities by using light absorbing properties of the sample.

The oil gets contaminated mainly due to the aging, moisture, sludge, acid metal particles and other compounds produced due to aging insulation (cellulose) which changes the oil chemical and physical properties. Oil oxidation occurs in the presence of oxygen and also cause sludge formation. Transformer life can be maximized by controlling the temperature, oxygen and water levels on which aging phenomena strongly dependent. Water and furan are the key indicators for the life expectancy of power transformer metal particles are also found in the oil [2].

The solid insulation (cellulose) is the major element of the insulation system and can be analysed with the measure of degree of polymerization. As we know it is monomer units in the polymer and is to determine the condition of paper winding insulation which we take from transformer. The average length of cellulose chain is measured by tensile strength of the sample.

II. UV SPECTROPHOTOMETER

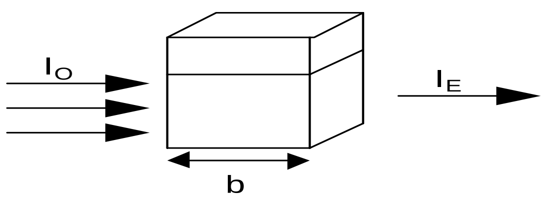
Ultra violet spectrophotometry is the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength. A spectrophotometry is an accurate and sensitive method to analyse impurities in transformer oil by using light absorbing properties of the sample. The light passes through oil sample containing various contaminations is decreased by that fraction being absorbed, detected and measured as a function of wavelength[2]. Where wavelength, λ is the distance between two successive peaks. Absorption spectroscopy provides a measure of how much light is absorbed by the oil sample which can be calculated as

= - log (———)

Where   is the absorbance, S is the sample intensity at wavelength λ, D is the dark intensity at wavelength λ, R is the reference intensity at wavelength λ..

G. Transmittance and absorbance

It is difficult to measure absorbance of light. Instead; we measure transmittance that is able to pass through a solution of molecules. A Spectrophotometer measures the intensity of light entering a sample and compares this to the intensity of light move out from the sample



I0 = Intensity of incident light

IE = Intensity of exiting light

B = Path length of sample

Fig 1 Transmittance of light in a spectrophotometer. And

Transmittance = I_0/I_E

There are three things that will affect the amount of light move out from the sample. First, the concentration of molecules in the solution affects the transmittance. Each molecule absorbs light. As number of molecules in solution increase, there is increase in the photons absorbed. Therefore as increase in concentration of sample, there is decrease in transmittance. Second, the length of the sample path will affect the transmittance. By increasing pathway so light pass through sample and there is increase in number of molecules which interact with light and in effect increase the concentration. Third, the transmittance will be affected by specific properties of the molecules. Molecules absorb light at different efficiencies and at different energies. Therefore, the transmittance will be dependent upon the specific molecule in solution and the wavelength of light being passed through the sample

In the graph the horizontal axis is normally the wavelength and vertical axis absorbance measures amount of light absorbed by the sample. Heptanes solution is used as baseline for the absorbance measurement and observing the transmitted light before cell is filled with oil. This value is stored and used to calculate absorbance based on the measured light as a function of time.

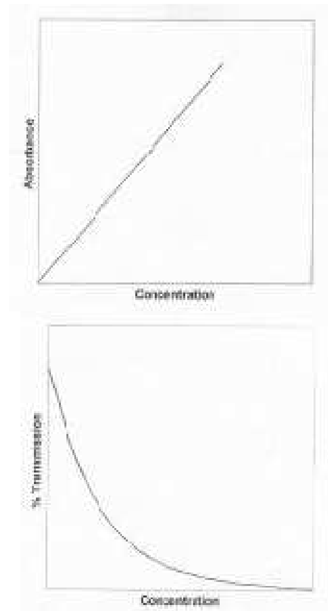


Fig 2 Concentration increases, light Absorption increases linearly. And as concentration increases, light Transmission decreases, exponentially.

H. The Beer Lambert law

The Beer’s law provides a linear relationship between absorbance and concentration of an absorber of electromagnetic radiation such as [2].

A =   × b × c

Where *A* is the measured absorbance,

λ is a wavelength dependent on absorption coefficient,

b is the path length, and

c is the sample concentration, also

A =   ×b ×c

Where   the wavelength is dependent on the molar absorption, the λ subscript is often dropped with the understanding that a value for ε is for a specific wavelength. If multiple species that absorb light at a given wavelength are present in a sample, the total absorbance at that wavelength is [2]

The sum due to all substances:

A =   ×b ×) +   ×b ×) +..........

The subscripts refer to the molar absorption and concentration of different absorbing impurities present in the sample. Experimental measurements are made in terms of transmittance T which is defined as [2]

T = —

Where P is the power of light after it passes through the Sample and is the initial power of the light. The relation Between A and T is defined as:

A = = - log —

Ultra violet spectrophotometer provides reasonable information on the health of the power transformer to plan the cost effective maintenance, retirement and operational criteria [2].

III. PRACTICAL USE OF SPECTROPHOTOMETER

The spectrophotometer provides the over all assessment of the transformer with precision and the correlation between the transformer aging and UV trend can be easily established. To measure the absorption of radiant energy there are basic components like a stable source of radiant energy (Light). A wavelength selector is used to isolate desired wavelength from source (monochromator). A transparent container (cuvette) is used for the sample and the blank (as reference). A radiant detector is used to convert the radiant energy and readout device that displays the signal from the detector

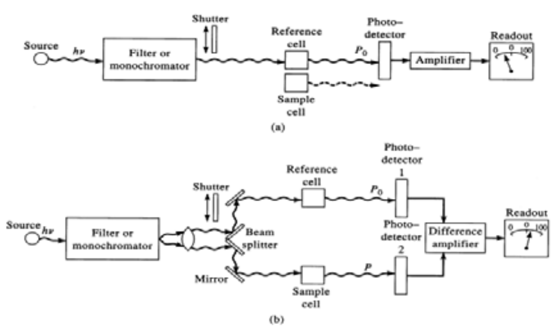


Fig 3 (a) Single and (b) double beam uv spectrophotometer.

UV/VIS spectrometry tells us about electronic transition in atom and molecules, spectra are produce when electrons and molecules or atoms are move from one electronic energy level to another higher energy. In doing so the absorb energy equal to the gap between the two levels compound that absorbed in the visible region such as some transition metals compound and organic dies are colour those that absorb only ultra violet region are colour less.

Inside UV visible spectrophotometer there are usually two light sources one give us visible light and other ultraviolet. Tungsten lamp is used for visible light and deuterium lamp is used for ultraviolet light.

Mirror direct lights from appropriate source into the monochromator. It split light the light into consequence wavelength l. Red is around 700 nm and blue is around 400 nm. Wavelength shorter then 350 nm are called ultraviolet. Shorted wavelength light has higher energy.

Source produces white light (i.e. included all wavelengths all colours') the instrument scan through spectrum sending different wavelengths of light through sample in sequence. This is done by grating which rotates. A single wavelength passes into the modulator which consists of a rotor with mirror on it. This chops the light into two beams. One beam is passes through the sample cell and other passes through the reference cell. So the instrument is referred as double beam instrument. Both sample and reference beams are directed by mirrors on to the detector. This compare there intensities and send the signal proportional to the ratio of their intensity to the computer to control the instrument. The logarithm of this ratio gives us quantity called absorbance which is measure of how much light is absorbed by sample at particular wavelength.

Ultraviolet visible spectra are usually rewan solutions light does not normally passed trough the solid samples. There we take two cubec one used as reference and other will contain the solution or oil. Cubec made glass or plastic if visible region of spectra is required. UV light is absorbed by glass or plastic. Then put those two cubec in sample holder. The led is closed to prevent light from laboratory interfering with spectrum.

Fig 4: Lab set up for measuring the spectral response of transformer oil.[3]

IV. EXPERIMENTAL ANALYSIS

An experiment is taken on different sample of oils which gives the condition of transformers. Nine transformer rated at 6.3 to 100 MVA respectively were selected to perform the oil spectrophotometry test. The new transformer oil absorbance exhibits its characteristics between 200 to 350 nm wavelength and spectrophotograph represent that absorbance increase wavelength with oil deterioration and contamination due to aging property of insulation system.

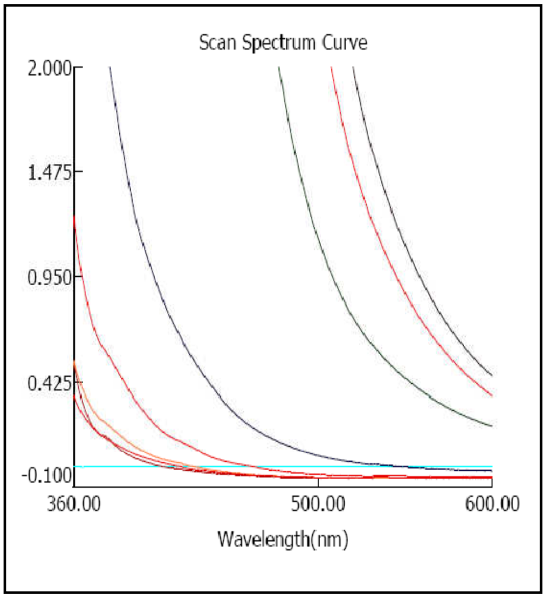


Fig 5: Absorbanse vs wavelength characterstics of different sample of transformer oil.

As shown above, the graph is drawn between wavelength (nm) and absorbance. Heptanes solution is used as baseline for the absorbance measurement and observing the transmitted light before cell is filled with oil. In this graph shows the different spectrum curve of new and aged oil. The new oil have short wavelength as compared to degraded or aged oil because it can absorb less amount of light. And if there is any contamination or metal particles present in oil, it take large time to pass through the solution so the wavelength increases.

The absorbance spectrophotograph for the scrapped oil exhibits high absorbance level over the uv spectrum from 200-900 nm. This shows the variety of contamination including very high carbon and water contents. Above results demonstrated the level of contamination present in the oil and interpreted the condition of the oil.

V. CONCLUSIONS

UV-Spectrophotometry is most effective technique for oil dehydration or oil replacement. The technique may prove to be an alternative to oil conductivity assessment. It also indicates the dielectric response and aging assessment of transformer oil. The Ultraviolet-to-Visible spectral response of transformer oil can be measured instantly using relatively cheap equipment with no need to an expert person to perform the test uv spectrum analyse the qualitivle and quantitatively with respect to contamination present in it. A good return on the capital investment can be achieved as well as an extension in life is possible leading to proper asset management

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