Characterization of mineral insulating oil in view of its Power factor and dielectric strength

Ashraf Yehia El-Naggar

Egyptian Petroleum Research Institute, Nasr City, Cairo, Egypt.

Chemistry department, Faculty of Science, Taif University, Kingdom of Saudi Arabia.

Abstract

Power factor tests, dielectric strength and physicochemical measurements of mineral insulating oils in Egyptian power station during operation were studied. It has been found that the transformer oil samples matched with the international standard methods, indicating that these oils are in a moderate useful state. The studied oils have low dielectric strength compared with the other transformers may be due to water contamination which reflected their low interfacial tension, also reflecting the decrease in their safety around high voltage equipment. All studied insulating oil samples during operation exhibit low total sulfur content values within the values of the international standard. This study reflects the change occurs in the oil during working and the life of a power transformer.

Key Words: Power factor, Dielectric strength, Transformer oil, total sulfur content

I. Introduction

Insulating oils must have: (a) low viscosity for easy flow and efficient heat transfer, (b) low pour point when using the oil in cold outdoor weather service, (c) low solvency power, (d) high oxidation stability, (e) reduced gassing tendency, (f) high flash point to reduce fire risk, (g) low vapor pressure at high temperatures, and (h) negligible amounts of contaminants which have adverse effects on the electrical properties [(1)]. Insulating oil plays very important roles in the power transformer as insulation and heat transfer medium, many researches [(2-4)] and studies have been reported and examined for decades to understand its physical and molecular characteristics, behavior under certain condition such as high temperature, techniques to procure the best transformer oils, and so forth.

Mineral transformer insulating oils are highly refined from predominantly naphthenic crude oils to yield mineral insulating meeting specification. It is mainly a mixture of hydrocarbon compounds of three classes: alkanes, naphthenes, and aromatic hydrocarbons that may be included polar atoms of nitrogen, oxygen and sulphur [(1)] which may greatly influence the chemical and electrical properties of the oil. Mineral transformer oil is basically a mix of hydrocarbon compounds that can decompose as a result of oxidation mechanisms

favored by oxygen, temperature and metals acting as catalysts [5]. These oxidation reactions induce breakdown of hydrocarbons into free radicals, which are highly reactive molecules that combined with oxygen form peroxide radicals in a chain of reactions [6, 7].

II. Experimental

The reliable performance of mineral insulating oil in an insulation system depends upon certain basic oil characteristics which can affect the overall performance of the electrical equipment. In order to accomplish its roles of dielectric, heat transfer agent and arc-quencher, the oil must posse's creation basic properties. The main feature of this study is the use of the internationally adopted testing procedures for the acceptance of transformer oils and clarifies experimentally their electrical, physical and chemical properties. These tests are specified by the international Electro-technical Commission (IEC)[8] and similar bodies and they are considered to be the main criteria for the judgment of the transformer oil insulation quality.

II.1. Measurements of power factor and dielectric constant:

Liquid power factor and dielectric constant of the studies transformer oil samples were measured according to ASTM D 924 and ASTM D 877 standard methods respectively. There is a relationship between the power factor, and the dielectric constant or permittivity. They all relate to the dielectric losses in an insulating fluid when used in an alternating electric field. The purpose of these tests is to determine the insulating properties of the oil. They are influenced by the presence of particles and moisture.

The measurements are made in specially designed cells that are machined to precise dimensions. The measurements are done at precise temperatures, usually 25 and 100 ^{o}C, thus the cells have to be kept at a constant temperature. The actual measurement is one of comparing the capacitance of the cell filled with the insulating fluid sample in a sensitive electronic bridge circuit. The result is usually expressed as a percentage for power factor.

II.2.Physico-chemical measurements

Ten transformer oil samples were collected from top and bottom of each transformer of both unit 1 and unit 2 in Egyptian power station. These oil samples were subjected to physicochemical properties in order to study the transformer oil characteristics. These properties of the transformer oils such as: sulfur content, interfacial tension (IFT), and neutralization number (NN) were measured according to the standard methods D 4294, D 1500 and D 971 respectively.

III. Results and Discussion

Insulation plays an important role in the life expectancy of the transformer. Oil suffers continuous deterioration and degradation due to the sustained application of the electric and cyclic thermal stresses because of loading and climate conditions. This may be hazardous to the electric equipment and installation. An important part of the oil degradation is caused by air in contact with the heated oil in the apparatus, which by oxidation results in the oil degradation. Hot cellulose is also a source of oxygen. In order to reach these aims it is indispensable to gather detailed information about the operation conditions of transformers, which is usually done by various kinds of oil analyses like the standard oil test and the Furan analysis.

III.1. Physico-chemical measurements:

As mentioned previously, the experiments which are described have been carried out on each studied transformer oil samples. The physico-chemical properties of the studied transformer oil samples are given in Tables 1, 2. Field examination of insulating oils includes the presence of cloudiness or sediment and general appearance as well as color examination. As oil aged, it will darken gradually. It was shown that, all studied transformer oil samples have an acceptable degree of color appearance, except excitation ones which has a dark color that may be due to the presence of free water or particles which may be detrimental to continued operation of the equipment . The color of the oil by itself should never be used to indicate the oil quality, but attack our attention to carrying out further tests.

Neutralization number reports the relative amount of a number of oil oxidation products, primarily acids, alcohols and soaps. As the oil continues to oxidize, acid number increases gradually. Acid number provides guidance as to how far oxidation of the oil has proceeded.. From Tables 1 and 2, it has been found that the excitation transformers of both units 3 and 4 exhibit highest values than the other transformers but within the acceptable values indicating their lower efficiencies.

Interfacial Tension measures the strength of an interface that will form between service aged oil and distilled water. Because decay products of oil oxidation are oil and water soluble, their presence will tend to weaken the interface and depress the interfacial tension value. From Tables 1 and 2, the studied transformer oils during operation exhibit acceptable values of interfacial tension greater than 25 dyne/cm except the excitation transformers which have unacceptable interfacial tension values below 25 dyne/cm. Below this value the oil is very contaminated and must be reclaimed to prevent sludging and shorting transformer life

which begins around 22 dyne/cm. From the IEC specifications, the minimum value of flash point should not be less than 145 ^{o}C.

Sulfur compounds can improve the oxidation stability of lubricating oil and some of them are considered to be natural antioxidants [9] not all sulfur compounds have favorable effects. There are corrosive and non corrosive sulfur compounds in bas oil, since these days transformer base oil is mostly hydrotreated, there are only small amount of mercaptans and disulfides. Tables 2 and 3 give the total sulfur content (TSC) in the studied transformer oil samples during operation. It has been found that all these oils exhibit low TSC values within the TSC values of the international standard.

III.2.Electrical measurements

The high-dielectric strength of transformer oil helps ensure safety around high voltage equipment. This property is essential wherever the oil is used as an electrical insulator. In order to maintain a high dielectric strength, the oil must be kept clean and dry. Tables 1 and 2 indicate that excitation transformers have low dielectric strength compared with the others may be due to water contamination, reflecting the low efficiency of these oils as electrical insulator and decrease their safety around high voltage equipment. Every effort should be made to use the entire drum once the seal is broken to help prevent water contamination, which quickly degrades the dielectric strength of the oil. If contamination is suspected, always inspect the drum and test the oil for dielectric strength before use.

The high-dielectric strength of transformer oil helps ensure safety around high voltage equipment. This property is essential wherever the oil is used as an electrical insulator.

Table 1: Power Factor, Dielectric strength and some physicochemical characteristics of the Unit #1 transformer oil samples

Samples ID	The Tests	Power Factor @ 90^{o}C	Dielectric Strength, Kv/2.5 mm	Neutralization Number, mg KOH/g	Interfacial Tension, dyne/cm	Sulfur Content, wt%
Unite 1 (TOP)		0.0005	72	0.007	41	0.01
Unite 1 (bottom)		0.0003	76	0.017	44.5	0.01
Unite 1 AUX (TOP)		0.0002	76	0.023	45	0.02
Unite 1 AUX (bottom)		0.0001	68	0.019	44	0.02
Unite 1 Excitation Trans		0.0009	62	0.110	21	0.018

Table 2: Power Factor, Dielectric strength and some physicochemical characteristics of the Unit #2 transformer oil samples

Samples ID	The Tests	Power Factor @ 90°C	Dielectric Strength, Kv/2.5 mm	Neutralization Number, mg KOH/g	Interfacial Tension, dyne/cm	Sulfur Content, wt%
Unite 2 (TOP)		0.0003	88	0.011	50	0.01
Unite 2 (bottom)		0.0001	92	0.027	46	0.01
Unite 2 AUX (TOP)		0.0001	96	0.024	42	0.02
Unite 2 AUX (bottom)		0.0001	96	0.027	40	0.02
Unite 2 Excitation Trans		0.0008	64	0.135	21	0.01

In order to maintain a high dielectric strength, the oil must be kept clean and dry. Tables 2 and 3 indicate that excitation transformers have low dielectric strength compared with the others may be due to water contamination, reflecting the low efficiency of these oils as electrical insulator and decrease their safety around high voltage equipment. Every effort should be made to use the entire drum once the seal is broken to help prevent water contamination, which quickly degrades the dielectric strength of the oil. If contamination is suspected, always inspect the drum and test the oil for dielectric strength before use. Liquid Power factor involves measuring the power loss. Water contamination and the decay products of oil oxidation tend to increase the power factor of the oil. Excitation transformers of unit 3 and unit 4 exhibit high power factor (Tables 1 and 2) which is a direct indication to the presence of materials harmful to the insulating paper and to the continued operation of the transformer. The insulating oil analysis is important in knowledge the life of a power transformer and the change occurs in the oil during working. From the measured oil data, it has been concluded that eight studied insulating oil samples from main and auxiliary transformers have oil data within the required specifications of the professional societies that oversee transformer oils such as British Standard BS [(10)], International Standard or Westinghouse Specification.

Except the Excitation transformer which has transformer oil data lower than that of the international specifications due to abnormal electrical or thermal stresses.

Conclusion

The excitation transformers of units 1 & 2 have low dielectric strength compared with the other transformers may be due to water contamination which reflected their low interfacial tension, also reflecting the low efficiency of these oils as electrical insulator and decreases their safety around high voltage equipment. The electrical properties of insulating oil are a powerful manner for knowledge the life period of power transformer and the change occurs in the oil during working.

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