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Modify the Performance of Electrical Transformer by Analysis Oil Aged and Paper Insulation with Nanoparticales .

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Abstract:

A gradual change in the state and properties of the oil transformer due to aging, which generally leads to break down. Aging of the mineral oil cause permanent harmful change of the ability insulation system.

Aging of the mineral oil and water content of paper insulation are simulated at the laboratory by putting the samples of the oil and pieces of insulation paper in a rig (transformer manufactured) and exposed to different temperatures ($20C^o$, $40C^o$, $60C^o$, $80C^o$) for specific durations of time to analysis and improve the performance of the transformer.

In this research, the electrical and physical characteristics for the mineral oil and paper insulation have been studied and then repeated by the addition of different concentration of Nanoparticales (ZnO) (0.01, 0.03, 0.05, 0.07)gm/ml then compared with the electrical properties of the pure mineral oil and paper insulation without (ZnO) nanoparticales

1. Introduction.

The electrical insulation role is very important to provide a foundation for the proper operation of the electrical equipment. In general, most of electrical equipment consist of materials for conductive use to transfer electrical energy and materials for insulate to prevent faults like short circuit among the conductors.**[1]**

The insulation function is by using liquids to transmit the heat far away from the electrical equipment like a transformer which have a core and coils (windings), so it needs insulation medium.**[2]**. In general 90% of the electrical transformers uses mineral oil to insulate the materials. Under the service conditions, insulations are always subject to gradual deterioration because of electrical, mechanical and thermal stresses. The thermal stress which occur at the insulation system due to electric heating , discharge and operation at high ambient temperatures because of the Joule heating (losses)which is I^2R . The interaction through the stresses led to early aging of the insulation which causes a failure, so that efficiency reduces. **[3]**.The Nanoparticales are relatively new class of particles which have a size about (1-100) nm.

Generally these particles made of metal or oxide of the metal, which increase the convection and the conduction coefficients, so it enhance the rate of heat transfer out of coolant.**[4]**

The thermally accelerated process for aging experiments are performed to foretell the behavior of mineral oil and insulation paper for long time. The experiments for aging have been managed at range of temperate from (20 to 80)C^o for time period up to 4000 hours.

In 2008, Hweng etal **[5]** among the researched which used the simulation that showed the oil transformer with Nano particles have a high break down voltage than the pure oil.

In 2010, Yue-faan et al **[6]** developed another type of oil transformer by using Nano particles (TiC_2) to boost the mineral oil for transformer to enhance the dielectric break down voltage.

In 2012, Li et al. **[7]** showed that (Fe_3O_4) Nanoparticales in oil vegetable insulating was used to improve the dielectric and break down voltage properties of vegetable oil.

The transformer oil and water content are absolutely not good combination as it overlap great electrical properties of the mineral oil. The paper insulation is effected by the water contented in the transformer oil. The paper insulation is highly hygroscopic, therefore it absorbs water if it content in transformer oil, and this will lower the age of transformer. When transformer is loaded, the temperature of oil increase, so the solubility of water will increase and cause high moisture for the insulation paper.**[8,9]**

The objectives of these experiments are to explain the nature of mineral and insulation paper properties like degradation and electrical detraction due to the aging and water content .The electrical tests, dielectric constant , break down voltage and resistivity which done for the mineral oil by using dielectric device , breakdown voltage device and resistivity measurement device respectively also for insulating paper properties the interfacial polarization spectrum is used.

2. Electrical and physical properties:

In the electrical terms, the dielectric constant represent a ratio of stored energy at the materials by the voltage applied, relative to energy stored at the vacuum.**[10]**

The breakdown voltage for insulating liquids is a measure for liquids ability to withstand stress voltage. The breakdown voltage explains the moisture presence and substances conducting at the mineral oil. **[11]**

The resistivity is a resistance of leakage current among an insulating materials. At a good transformer the oil resistivity must be high. The lower resistivity at oil transformer indicate that the moisture presence, and contaminating agent conductive. A high resistivity indicates that a fewer ion is free and low contaminates conductivity at the mineral oil for the transformer.**[12]**

The viscosity for the oil transformer is a resistance for oil flow in the transformer, this means the objection for transmit circulation. A good properties for the oil is low viscosity, therefore it offers lower resistance than the convectional oil flow, hence the cooling of transformer not affected. The oil viscosity should be increase as possible with the temperature decrease. In general any liquid if its temperature decreases, it becomes more viscous.

The materials which have amount of water described as moisture content. water content is usually measured in mass or in volume as including the materials in focus.

Water is very unwanted pollutant at the transformer oil and at the other transformer insulators. The moisture in oil cause decline density. The moisture content is proportional directly with transformer oil aging.

The paper windings are used always as an insulator and as a dielectric at the transformer oil, also the paper winding is affected adversely by the water content. **[13]**

3. Experimental study:

The procedure for experimental work is explained in this section. A system have been manufactured exactly similar to the real transformer, with a scale of (1/2) of the real size of distribution transformer (250KvA, 11/0.416 Kv) at Al-Dijail power station, the manufactured transformer consist of: - storage tank, pressure valve relief, temperature sensor and heater and paper insulation , as show in fig (1).

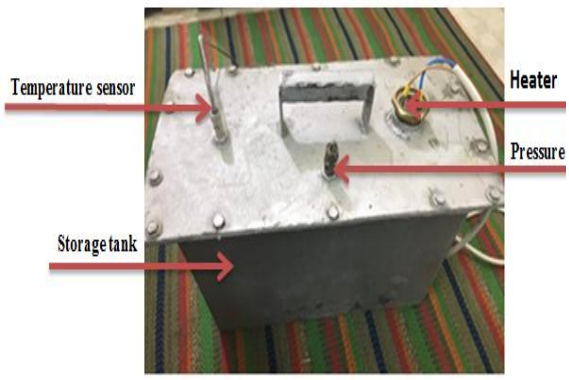


Fig (1) Manufactured transformer

- **Storage tank:** container (46 cm length, 36cm height and 20cm width)
- **The pressure relief valve (PRV):** A PRV is the valve which used to limit the pressure or to control system.
- **Temperature sensor:** A (TF101) temperature sensor
- **The heater:** copper , 220 V, 3Kv, (18*4.5)cm and above 80C^{o}.
- **Paper insulation:** laminate of 1mm thickness and 6 cm diameter.

Experimental procedure:

- The first step: testing the prepared aging mineral oil samples and paper insulation without Nanoparticales(ZnO) set into the aging container (transformer manufacture) at different temperature (20, 40, 60, 80) C^{0} for different duration time.
- The second step: The viscosity and water content properties of the new mineral oil and the used oil (aging oil) are tested at different temperatures (20, 40, 60, 80) C^{0} for different duration time (0, 1080, 2160, 3240, 4320) hours.
- The third step: Nano fluid are prepared at Nano technology research center at the University of Technology by using ultrasonic vibration device. The preparation of Nano fluid is done by adding the Nano particles to the mineral oil and then mixed by the powerful tool which called ultrasonic vibrator. The mixture of mineral oil and Nano particles is scattered by ultrasonic mixing (to avoid the agglomerate) for three hours at different concentration (0.01, 0.03, 0.05, 0.07)g/ml, where the density of (ZnO) nanoparticales is (0.38g/cm^{3}).
- The fourth step : The other aim of this work is improving the dielectric strength and breakdown

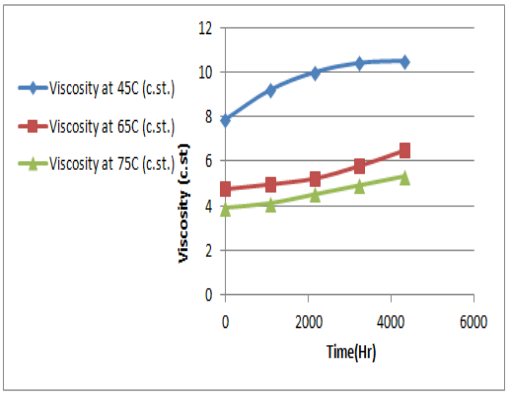
voltage properties of mineral oil and paper insulation by mixing a Nano particles (ZnO) with a mineral oil samples at different concentrations (0.01, 0.03, 0.05, 0.07)g/ml for different duration times(0, 1080, 2160, 3240, 4320) hours at different temperatures(20, 40, 60, 80) C^0.

- The fifth step: The test for insulation papers is done by immersing the samples horizontally in the container of the oil with and without nanoparticales then taken out to cool at room temperature and to absorbing moisture. The weight of samples of papers insulation are aged by the moisture of air to obtain the level of water content, then these samples are placed at the manufacture transformer.

All these tests are implemented at ministry of oil petroleum R&D center at analytical laborites department.

. Result and Discussion:

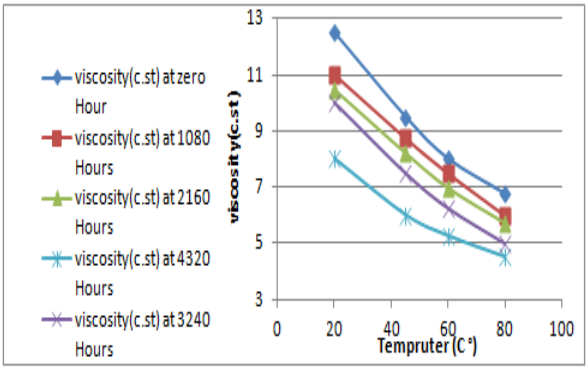
In this section an experimental results have been explained, analyzed and discussed as following:-



Fig(2) The Viscosity of oil samples for different time.

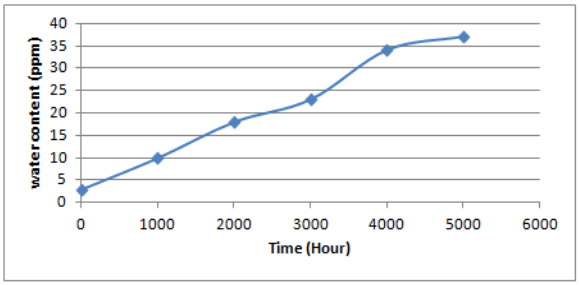
1. Fig. (2) Explain the results of viscosity (C.S.T) with the aging duration time (0, 1080, 2160, 3240, 4320) in hours which done by using the viscometer device. The viscosity of mineral oil increased as time increased . The results showed that the mineral oil degradation have affected the oil viscosity.

2. Fig. (3) explain the results of the viscosity variation (C.S.T) with temperature from (20-80) C^0. The viscosity decrease as the temperature increase with different duration aging time, because when the oil heats up , its molecules become excited and then begin movement. The energy movement is enough to reduce the forces which link the molecules with each other, so the oil becomes less viscous and the viscosity decreases. A decrease of temperature by $1C^o$ causes about 10% increases in the viscosity.



Fig(3) Viscosity of oil samples for different temperatures

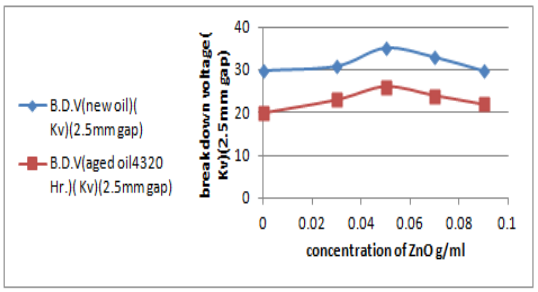
3. Fig. (4) Explain the results of water content (PPm) with the time in hours. The water content increase as time increases. The mineral oil which reaches a saturation point of water content it's separated from free water. First contamination in mineral oil is the free water. The relationship between the temperature and water solubility is almost exponential. The saturation of water content ($W_{cot.}$) in mineral oil $W_{cot.}= K.e^{-H/T}$ [2].where the parameters K and H for the liquid depend on the properties of liquid itself. So, when the temperatures increase the water content at the mineral oil increase too.



Fig(4) Water content of oil samples for different time.

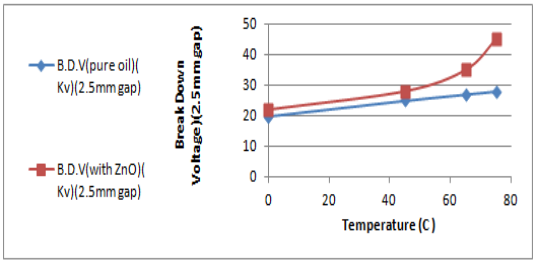
4. Fig. (5) Explain the results of breakdown voltage (Kv) tests for pure and mixed mineral oil with ZnO Nanoparticales at different concentrations (0.01, 0.03, 0.05, 0.07g/ml) at 40C^{o} and 20 ppm.

The breakdown voltage increases from (28 Kv) for aging oil to (34Kv)for new oil at (0.05g/ml) concentration. The breakdown voltage decrease when the concentration increase because the agglomeration of ZnO reduces the breakdown voltage , So the best concentration for this work is (0.05 g/ml).



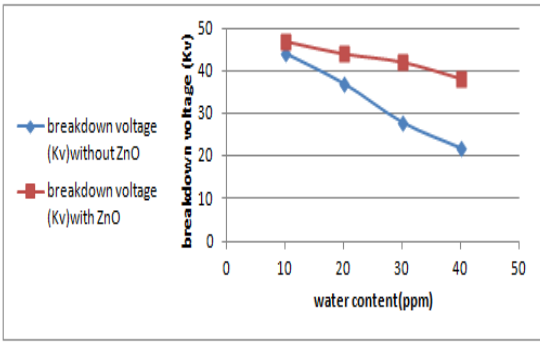
Fig(5) Break down voltage for oil samples with concentration

5. Fig. (6) explain the results of breakdown voltage (Kv) tests for pure and mixed mineral oil with(ZnO) Nanoparticales at best concentration (0.05)g/ml at different temperature (20, 40, 60, 80)C^{0} and at 20ppm water content . The breakdown voltage (Kv) tests is increased for pure and mixed mineral oil when the temperature is increased. The results of mineral oil mixed with (ZnO) Nanoparticales is (45kv)where is better than pure oil which is (29kv) at the same temperature , so the enhancement is about 35% which explain that one can say: when the added (ZnO) Nanoparticales are trap the electron by inclined catch the electron free released from the molecules of the mineral oil under electrical field which causes the increase of the breakdown voltage.



Fig(6) Break down voltage for oil samples with tempeartures

6. Fig (7) shows the relationship between the water content (PPm) and the breakdown voltage. The breakdown voltage for mineral oil with and without (ZnO) nanoparticales decrease when the water content increases. The addition of (ZnO) nanoparticales to the mineral oil produce a new mechanism which increases the breakdown voltage of mineral oil with (ZnO) nanoparticales. The (ZnO) nanoparticales improve the durability of the field strength of the mineral oil and qualify the harmful effects of the water content on the breakdown voltage for the mineral oil .



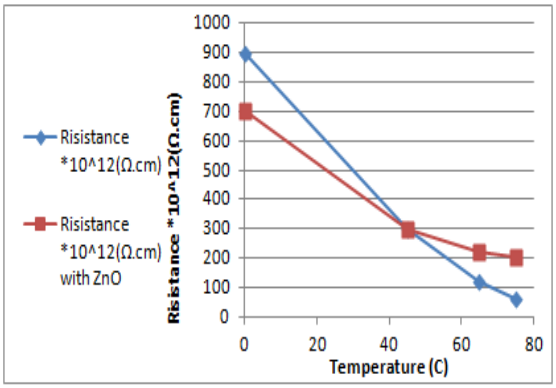
Fig(7) Break down voltage for oil samples withwater content

7. Fig. (8) Explain the results of temperature (C^0) against the resistivity (Ω.m),. This test done by using electrometer / high resistance meter.

The increase in temperature causes decrease in pure mineral oil resistivity and with Nano particles (ZnO)at (0.05 g/ml) concentration too.

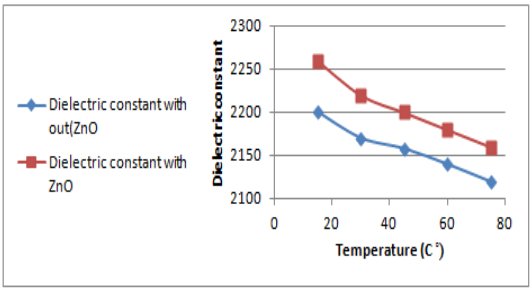
This change in resistivity for mineral oil happened by changing the activity of the atoms in materials due to the resistivity of conductors decrease at low temperature, but the resistivity at insulators increase at low temperature.

The result explain that the resistivity(ρ) of mineral oil increase when adding (ZnO) nanoparticales , So the resistance (R) increased due to the used of formula : R =ρL/A and according to Ohm law :R= V/I, therefore increasing the value of resistance decreases the leakage current, so a good insulator has a high resistance



Fig(8) Resistivity for oil samples with temperatures

8. Fig.(9) explain the results of dielectric constant tests for the pure mineral oil with the other which mixed with Nano particles (ZnO) at (0.05g/ml)concentration at different temperatures (20, 40, 60, 80)C^0, and at (20 ppm) water content

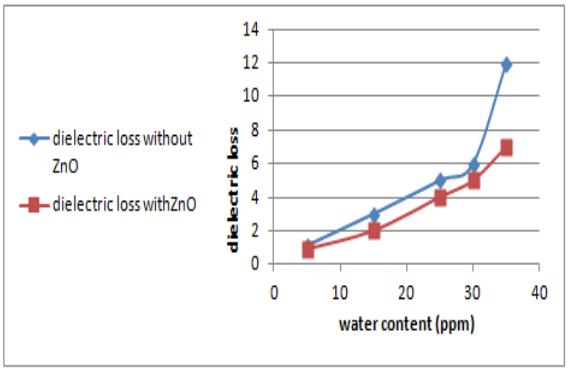


Fig(9) Dielectric constant for oil samples with temperatures

As shown in fig. (9), adding (ZnO) Nano particles to mineral oil at different temperature (20, 40, 60, 80)C^0 causes increase in dielectric constant about 24% , because (ZnO) Nano particles have a high dielectric constant.

when the temperature increase the dielectric constant decrease for both a pure and mixed mineral oil, to explain that: when added the (ZnO) Nanoparticales to the mineral oil, the molecules of (ZnO) place themselves among the molecules of the mineral oil , which are in randomly motion due to own an energy. The molecules of mineral oil rotate and arranged in line with a field when adding an electrical field. After putting (ZnO) Nanoparticales its atoms tend to catch the electrons of the mineral oil and reduce the energy for molecules of mineral oil. Hence, the molecules are stratify with each other when electric field is applied, so the dielectric constant for mineral oil with (ZnO) Nanoparticales is increases more than with that of pure the mineral oil.

9. The fig (10) shows the water content (ppm) with dielectric loss of paper insulation at ($40C^{o}$) with and without (ZnO) nanoparticales. As shown in figure , when the water content increase the dielectric loss increases too for both cases. The addition of (ZnO) nanoparticales suitable to decreases the dielectric loss of paper insulation when the temperature reach to ($80C^{O}$). The dielectric loss of the paper insulation with (ZnO) nanoparticales is less than with that without , so the nanoparticales (ZnO) enhancing the dielectric loss of paper insulation at ($80C^{o}$) about 53%.



Fig(10) Dielectric constant for oil samples with water content (ppm).

6. Conclusions:

It have been observed from the study that : the properties of the mineral oil insulating are affected by aging operations, the aged mineral oil for the transformer causes a lower voltage breakdown. Also have noticed that the relationship between the viscosity and temperature is inversely proportional Also have seen that the presence of moisture in oil of the transformer (water content) causes lower voltage breakdown and realized that the life of oil is more extended by the use of (ZnO) Nano particles, in addition that **t**he resistivity of mineral oil increased when adding (ZnO) Nano particles. So the (ZnO) Nano particles can be used with mineral oil transformer and other electrical equipment to improve the dielectric characteristic for the mineral oil without the need to another requirement for electrical insulation**,** also the (ZnO) nanoparticales modified the paper insulation has shown less dependence of breakdown voltage on the water content, and when temperature is higher more ($80C^{o}$) causes adverse impact on the paper insulation with nanoparticales.

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