Affecting Factors Titanium Oxide of Nanoparticles for the Electrical Effect on Insulation Resistance of the Transformer Oil

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***Abstract*— In most cases, The electrical insulation of the transformer oil will be exposed to different internal problems, such as short circuit , over voltage, over load, over excitation and etcetera. The insulation of transformer will be sever decreased into minimum value. This requires some treatments of oil liquid ,such as refining or replacing the damaged oil with a new, which is a very expensive process. In this paper, the Insulation Resistance (IR) of transformer oil will be enhanced by using nanoparticles NPs. Titanium oxide (TiO2) one of them, which will be used in this experiment. The (NPs) improve the insulation, physical and chemical properties of transformer oil. The breakdown voltage will be tested for pure oil and after the addition (TiO2) according to IEC standard methods. The results of this study indicated that addition of TiO2 in certain quantities of pure oils can be affected the Insulation Resistance (IR) and electrical breakdown voltage. A comparative study was conducted to identify the effects of using nanoparticles in pure transformer oils to ensure their effect on electrical Insulation Resistance (IR). The results are indicated an increasing in the breakdown voltage and the dissipation factor of the transformer oil, thus results using nanoparticles oil higher than pure oil.**

***Keywords*—Nanoparticles (NPs), Insulation Resistance (IR) test, breakdown voltage (BDV) test and Titanium oxide (TiO2).**

I. INTRODUCTION

The transformer is one of the equipment used in the transmission and distribution of transmission line so it is the spirit of the system because it converts voltage and current with the stability of power and frequency. The lifespan of the transformer is particularly important in electrical systems because it is static equipment ranging from 35 to 40 years. Electrical faults on the transformer reduce its lifespan and this is due to the low level of electrical insulation of the transformer [1-4]. The internal insulation of the transformer is very important, so it determines the validity of entering the service or excluding. The Mineral oils are used to isolate and cool the transformer coils and to give an indication of the internal state in order to determine its faults. The gas and chemical analysis of the transformer oil shows the extent of its diseases. Therefore, if there is a problem in the oil, the treatment must be either by replacing or refining oil and both methods are very expensive [5-7].

Nanotechnology is a scientific revolution in the fields of engineering, medical and scientific. It is based on the substitution of the atom material, which produces a new material completely different from the original material has new physical and chemical properties. Previous studies have pointed to the importance of using nanotechnology to improve the properties of transformer oil. Therefore, nanoparticles have been used to improve the age of limitation of the transformer and can extend its lifespan to double for paper [4]. It is also used in improving electrical insulation, dissolving gases, improving chemical properties and improving viscosity properties [9]. The nanoparticles of the transformer oil have become as important as the medication for its diseases. it was found the kinds of nanoparticles (Fe3O4,CuO,ZnO Al2O3and TiO2) can increase both positive and negative breakdown voltages under switching impulse voltage [11-15]. These materials of NPs are the most commonly used. It is cheaper, more stable and easy to prepare than other metal elementary substance[10].

Huge works for nanoparticles have been deployed to improve the properties of transformer oil. From this view, this research aims to improve (IR) of the transformer using nanoparticles. In this paper, The (TiO2) will be used. The paper was organized as follows. First, the oil will be processed by adding nanoparticles materials and then shedding ultrasonic waves and infrared ray on this oil. Second, the breakdown voltage test will be performed to ensure that the values are improved after the addition of the nanoparticles and then a mini model of the power transformers is immersed in this oil that will be used. The experiments will be conducted to test the (IR). Finally, the proposed mechanisms for the results obtained will be discussed.

II. EXPERIMENT METHOD AND TEST

A.Nanoparticles Preparation

Shell diala oil D was used in this work. The specification of this oil at highly refined include a density 895 kg/ m3. at 20 °C, a viscosity of 12 at 40 °C, a flashpoint of 135 °C, pour

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point of -40 °C, a breakdown voltage after treatment 70 kv and a dielectric dissipation factor of 0.005. There are factors that affect the quality of insulation of the transformer which is moisture, acidity and impurities. These factors cause problems when running the transformer may cause exit it from the service. In order to remove the impurity particles and treatment, the oil refinery machine must be used. The (MICAFIL) oil treatment machine that shown in Fig.1. This machine has several functions; heating the oil, drying the oil, disposing of dissolved gases and eliminating impurities. It includes heaters, a vacuum pump, a pump to push the oil, an entry filter, an exit filter and a trap for impurities. This machine is characterized by refining and transformer in the service at full load capacity.

Thus it will be obtained pure which will be essential for the manufacture of Nano oil. Nanoparticles was prepared by using TiO2 nanoparticles into the pure oil with a volume percentage by using sensitive balance in the lab. Using TiO2 nanoparticles were obtained from (Alpha Chemika) company as a powder with a particle size below 100 nm, purity 99.5% and a relative density of 4.26 g/ cm^3.

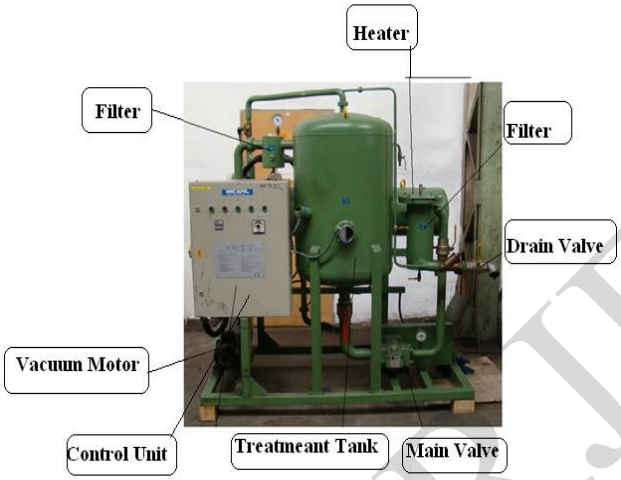


Fig 1. The (MICAFIL) oil treatment machine.

Ultrasound term called the audio frequencies exceeding 20 kHz. Ultrasonic waves are a high-frequency wave that the human ear cannot hear. Ultrasound uses certain effects in materials. For example, these waves can remove brain tumors and break up kidney stones. It can also be used to clean watches and other delicate devices and to mix chemicals. At some frequencies, these waves can generate enough energy to weld some metals. In this experiment, after the addition of the nanoparticles it causes melting of nanoparticles atoms in the transformer oil; so the properties of transformer oil will change. The frequency will be used at 65 kHz and the waves are concentrated on oil for two hours. The ultrasonic device is illustrated in fig.2.

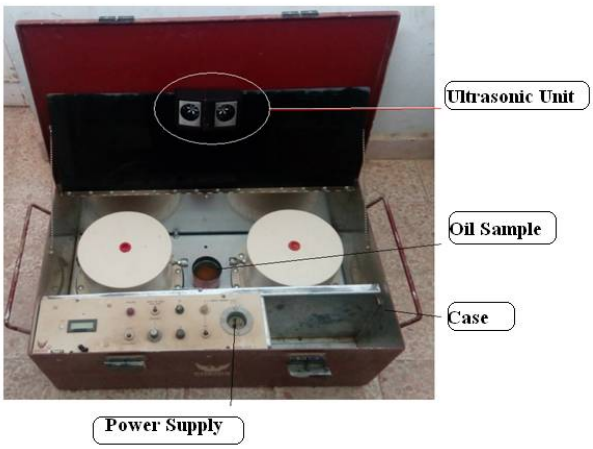


Fig 2. The ultrasonic device.

Despite the benefits of ultrasound, there are serious damage to it caused the increase of dissolved gases in the oil and the creation of bubbles of moisture. So it must be treated or the new oil will be damaged cannot be used. The presence of moisture in the oil caused a reduction in the (BDV) value. The dissolved gases are caused to raise the internal temperature of the transformer. Feature in the infrared, it penetrates the oil molecules to bring out the moisture and gases from them. So infrared is used in the treatment process. Philips lamp is used with rated power 250 watt and 230 volt. It has double reflector system to concentrate the rays on the oil. The radiation was given for two hours, with a five minute break every 20 minutes.

The basic steps for the preparation of nanoparticles can be summarized as follows. The (TiO2) is added to pure transformer oil where it is mixed using a mixing machine to ensure uniformity between the atoms of the material. The ultrasonic is then delivered for two hours to ensure that the oil is fully saturated with the nanoparticles. Infrared radiation has been used to avoid problems resulting from ultrasound. Eventually the nano liquid is obtained; Figs. 3 illustrated steps for nano fluid preparation. Therefore, oil processed by the nanoparticles is ready to test the breakdown voltage.

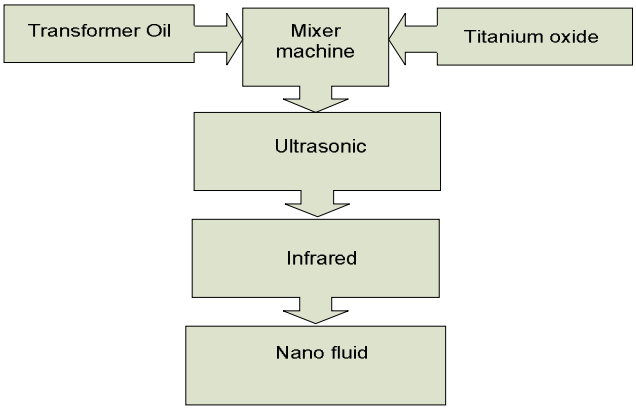


Fig 3. The Nano fluid preparation steps.

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B. Breakdown Voltage Tests

The new nano-oil was obtained, but before it was used in the megger test it was necessary to check the (BDV) of its electrical insulation. The AC breakdown voltage was measured in according to IEC 60156 standard. The electrode configuration used two spherical electrodes and made of brass [8]. The break down voltage device was used in test. Fig. 4 illustrates the breakdown voltage tester. The pure oil was put in the clean vessel and the gap will be 2.5 mm between the electrodes, now slowly rising voltage is applied between the electrodes.

The rate of rise voltage is generally controlled at 2 KV/s and observed the voltage at which sparking starts between the electrodes. The tester gives six values of breakdown were performed. The average value was used as AC breakdown voltage. All the experiment was calculated at room temperature. The pure oil will be replaced into the nanoparticles oil and the break down voltage will be run again. The results of the breakdown voltage of the pure oil and the nano oil will be based on the completion of the (IR) test.

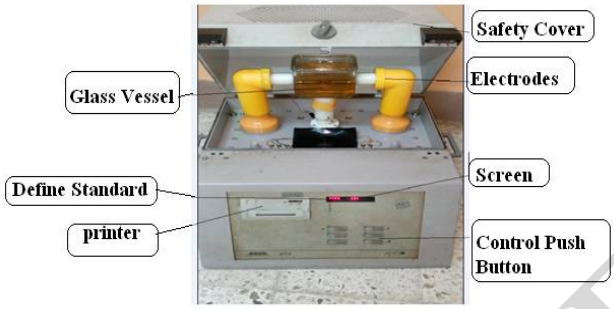


Fig 4. The breakdown voltage device

C. Insulation Resistance test methods

The Insulation Resistance device was used in this experiment is *(Chauvin Arnoux)* that shown in fig. 5. It has one unite for injected the power. the rated of voltage injected between 25v into 5kv. The Insulation Resistance is called megger test. The importance of this test to give a clear picture of a statement to the quality of isolation in the transformer. The specifications of the transformer that be used in this paper is given in the appendix A. The tank of the transformer will be filled with the pure oil at first, after that it will be filled with nano oil; the (IR) test will be run in each case.

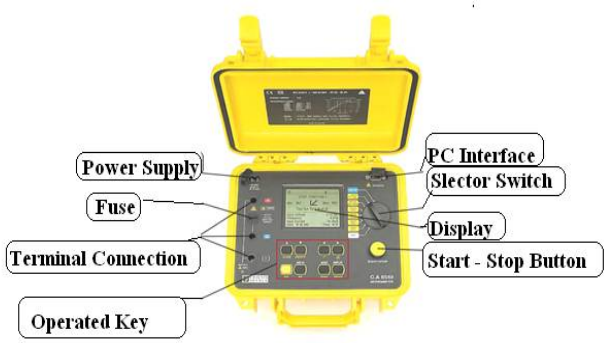


Fig 5. The (*Chauvin Arnoux*) device.

The purpose of this test is to ensure the quality of internal insulation between windings and ground. To make the test, the short circuit be made on the ends of the high and low voltage sides. The device is run by the start / stop button. The tank of the transformer will be filled with the pure oil at first. The positive terminal of the IR device is connected to primary side and negative terminal to secondary side, then operated the device at 500 VDC and recorded the results.

This test used to determine the condition of electrical equipment insulation. It's useful in providing an indication of deteriorating in insulation system. The measurement of transformer winding is carried out between (HV to G), (LV to G), (HV to LV). Fig. 6 shown the connection of (IR) device and transformer. The pure oil will be replaced by the oil of nanoparticles and the same steps of the previous experiment will be return.

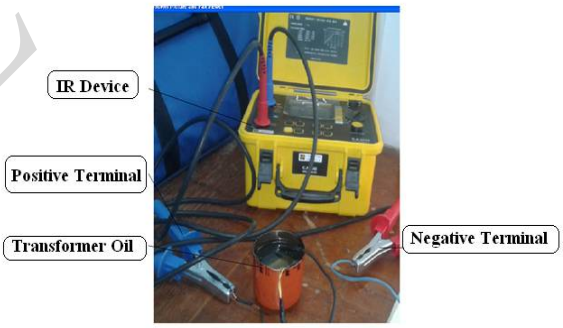


Fig 6. The Connection of (IR) Device and Transformer.

III. EXPERIMENT RESULT

A. Breakdown Voltage Measurement

Initially, the breakdown voltage was tested for pure oil, six readings of pure oil were taken at different steps of the breakdown voltage device and the average value was 47.5 kV as shown the results illustrates in fig.7.

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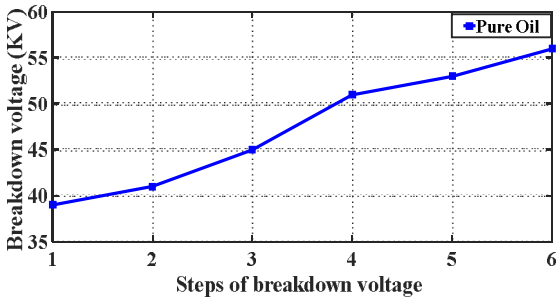


Fig 7. The breakdown voltage measurement of pure oil

The amount of titanium oxide added to the oil is important in the experiment because it is based on the value of the breakdown voltage of oil. So they are added in precision and with each addition of nanoparticles, the breakdown voltage of the oil is measured. The amount of nanoparticles added to the oil is shown in Fig. 8. The curve is shown the relationship between the breakdown voltage and the weight of TiO_2. At first the relationship is ejective after that it becomes inverse.

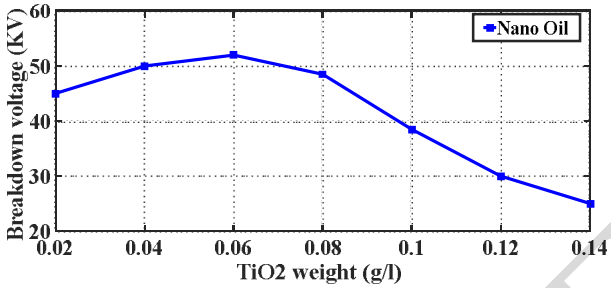


Fig 8. The Amount Of Tio2 Nanoparticles In Breakdown Voltage Test.

The amounts of nanoparticles are determined in milligrams per liter. The nanoparticles are indicated the improvement in the breakdown voltages as compared to the pure oil that shown in fig.9, but this value depended on the weight of nanoparticles in liter. At 0 (g/l) the pure oil only, when increased the amount to 0.06 (g/l) the maximum value of breakdown voltage was 52 KV, when increased the nanoparticles the breakdown voltage will be decreased the breakdown voltage of oil and properties will be changed. So, the increasing in ratio of nanoparticle mixture can lead to an adverse effect on the breakdown voltage of oil nanoparticles.

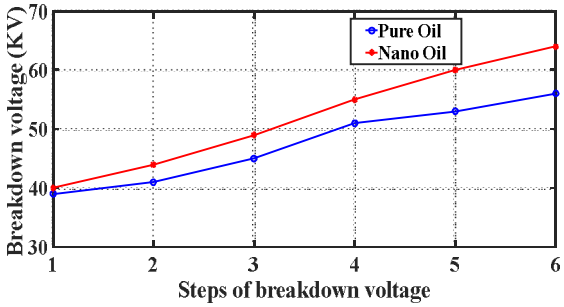


Fig 9. The Breakdown Voltage Measurement with Nanoparticles Oil and Pure Oil.

The effect of TiO2 nanoparticles on breakdown voltage in transformer oil was studied. The breakdown voltages of all the nanoparticles were higher than pure oil. The results of the break down voltage will be illustrated in table 1, which indicated the enhancement. The nanoparticles oil indicated the improving in the breakdown voltages that compared to the pure oil.

The TiO2 nanoparticles improved the breakdown voltage about 9.4%. The rate of improvement in the breakdown voltage leads to improved electrical insulation results of the transformer; these results are consistent with paper [8]. Thus, the highest value for the breakdown voltage is the addition of 0.06 g / l of titanium oxide. So it will be the ideal sample in the experiment to be filled with the transformer tank to conduct the dissipation factor test.

Table I. AC breakdown voltage results of pure oil and nanoparticles

Fluids	AC breakdown voltage (kV)	Enhancement breakdown voltage (%)
Pure oil	47.5	0
TiO2 NP	52	9.4

B. Insulation Resistance Measurement

In this test will be conducted at applied voltage 500V from the insulation resistance device. The insulation resistance device calculates insulation quality ratios in addition to the quantitative insulation resistance value, because they can be used to eliminate the influence of certain parameters likely to invalidate the absolute insulation measurement. Insulation resistance measurement values can be accomplished by two common tests, time resistance readings (Dielectric Absorption Ratio [DAR] Test) and polarization index (PI) test. The ratio of a 60 s reading to a 30 s reading is called the DAR. A DAR ratio below 1.25 the condition of insulation is poor or even dangerous results.

The PI test is a specialized application of the dielectric absorption test. The PI is the ratio of the insulation resistance at 10 min to the insulation resistance at 1 min. A PI of less than 1 indicates equipment deterioration and needs the immediate maintenance. The (IR) Test will be illustrated as shown in table 2, In this case the transformer will be immersed in pure oil and IR test will be operated. The results reflected the value when the insulation side is pure oil.

Table II. IR Test Of Pure Oil

Transformer windings	H – L	H - G	L – G
IR	784 GΩ	339.5 GΩ	539 GΩ
Leakage Current	683 pA	1.502 nA	946 pA
DAR	1.39	1.28	1.25
PI	2.1	2	2.1
Capacitance	< 1 nf	< 1 nf	< 1 nf

When changed the pure oil into nanoparticles, the results of IR test will be changed as shown in table 3, That be illustrated the value of IR test when added the NPs.

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Table III. IR test of nano oil

Transformer windings	H – L	H - G	L - G
IR	1176 GΩ	376 GΩ	634 GΩ
Leakage Current	434 pA	1.357 nA	804 pA
DAR	1.45	1.35	1.30
PI	2.2	2.1	2.2
Capacitance	< 1 nf	< 1 nf	< 1 nf

The electrical insulation resistance of the transformer is affected by the amount of nanoparticles added just like its effect on the breakdown voltage of the oil. Fig. 10 shows the added quantity and its insulation resistance. From the curve ,the best value was at 0.06 g / l of TiO2 and the insulation resistance value was 1034 GΩ.

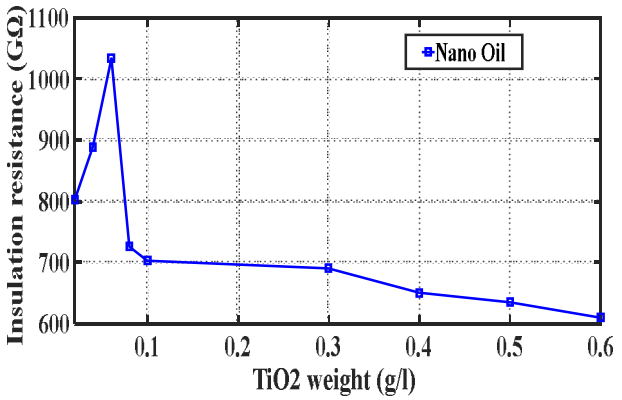


Fig 10. The Amount of Tio2 Nanoparticles in IR Test.

Insulation resistance test of transformer is essential type test. This test is carried out to ensure the lifespan of overall insulation system of an electrical power transformer. By using the nanoparticles the insulation resistance value of the transformer will be increased. The enhancement of the IR about 50% and the leakage current about 57% about. NPs were raised the results of PI test and DAR test. Comparing the value for Enhancement in IR (%) and Enhancement in $I_{Leakage}$ (%) illustrated in table 4.

Table IV. IR test of pure oil and nano oil.

Transformer windings	H – L	H - G	L - G
Enhancement in IR (%)	50	11	17
Enhancement in $I_{Leakage}$ (%)	57	15	17

The effect of TiO2 nanoparticles on IR test in transformer oil was cleared. The IR test of the nanoparticles was higher than pure oil. The value of insulation resistance with the nano oil is higher than the pure oil that shows in Fig.11. The results will be leaded to use these NPs in the electrical field. The results of the graph show the difference in results between pure oil and the use of nanotechnology to improve oil properties. There is no doubt that using nanotechnology is much better than not using it.

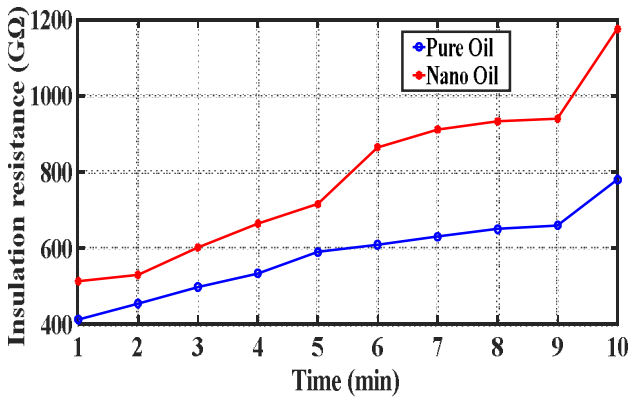


Fig 11. Insulation Resistance With Pure Oil And Nano Oil

IV. CONCLUSION

The paper demonstrated the utility of using nanoparticles to enhance the properties of the transformer and improve its efficiency. A model of a transformer similar to power transformers was made in power grids. Experiments were performed using pure oil and nano-oil. The main conclusions were summarized as follows:

1) The weight of nanoparticles is important and dangerous, so be careful while preparing the oil because the nanometer excess amount reduces the electrical insulation of the transformer and further deterioration.
2) The ac breakdown voltage of nanoparticles was higher than pure oil.
3) Nanoparticles have improved the electrical insulation resistance of the transformer. Also, the properties of transformer will be enhanced and the long life of transformer will be increased also.

APPENDIX

Table V. The Specification of the Transformer.

Serial no.	discriminative	Value
1	No. of phase	Single phase
2	Rated of power	500 VA
3	Voltage on primary	220 volts
4	Voltage on secondary	12 volts
5	Current on primary	2.27 Amps
6	Cooling transformer	ONAN
7	Frequency	50 HZ
8	Mfg. year	2016

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