

Enhancement the Properties of Electrical Insulation for Current Transformer Using Nano-particles

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Abstract: - Current Transformer (CT) is used to indicate meters and protective relay systems so; the maintenance process is very important and should make regularly. Routine maintenance is done via cleaning the insulations, tighten the screws and follow up the oil level. Periodic electrical tests are insulation tests, turns ratio test and a saturation curve test. Tests results give a good indication of the internal transformer status. In this paper, maintenance of the CT was made by a new proposed technique. In the proposed maintenance technique, the nanoparticles (NPs) are used to treat the low level of electrical insulation. The insulating medium of the CT is mineral oil, it is a hydrocarbon material. In normal operating situations there is no problem but during the faults and short circuit, the transformer oil is dissolved and carbon atoms are formed within the oil. Due to the repetition of operations, CT becomes invalid and must be replacing by another new one, because it is dangerous to individuals and equipment surrounding it. Nanoparticles attract these particles and raise the electrical insulation level of the CT. An electrical insulation test of the CT is performed before and after treatment to ensure the benefits of the new proposed method. The test results of proposed maintenance processes are compared with the traditional method according to the IEC Standards 60044. The results were studied using statistical analysis and explained substantial differences, when using nanoparticles. CT was raised the efficiency and prolonged life span.

Key-Words: - Current transformer; nanoparticles; insulation resistance test, dissipation factor and breakdown voltage test.

1 Introduction

Instrument transformers are used for transmission and distribution of the electrical power. It is divided into current and voltage transformers. Current transformers decrease the large values of current too small, standard values are used for instruments and protective relays. In substations, conductors and cables are the arteries of the electric power transfer. The CTs are as the sensors for the extent of the change in power flow. In normal operating conditions the current value is within the allowable limits of the operating system. But when a fault occurs, the value of the current is increased. This change is transferred to the controllers to disconnect the electric circuit breaker to preserve the safety of the electrical grid. In this case functions of CT are multiplied. Where it is used to read counters, protective relay systems, plant monitoring systems, fault records and SCADA systems.

The lifespan of CT is very Important rules that be ranged from 30 to 40 years. Routine maintenance is done regularly, daily, monthly and annually. Daily

maintenance is the daily traffic of the operator and the following works are performed; Check the virtual, follow the level of oil, make sure there is no leakage of oil, and make sure there is no strange sound issued by the CT.

In monthly maintenance the insulators are cleaned of dust and dirt to avoid flashover, also re-tighten the screws to ensure that oil is not leaked during operation. The annual maintenance is performed where electrical tests are as follows; excitation curve to determine knee point, insulation tests, polarity test, winding resistance test, turns ratio test, and break down voltage (BDV) test. The tests are aimed at the following; first, ensure that the current transformer is accurate in the turns ratio and thus ensure accurate meter measurement. Second, ensure that signals are connected to the protective devices and taking the appropriate decision alarm or trip. Third, ensure quality and efficiency of electrical insulation and energized equipment in maintenance reduces the risk of failure during the normal operation and the faults.

Laxity in the maintenance work and tests cause serious disasters. Of the problems, the internal insulation of the current transformer is defective due to aging and frequent faults. Also Lack of focus causes forgetting to open a secondary circle. This cause no current in the secondary coil, it has no anti-magnetic effect generated in the primary coil, and consequently to increase the voltage on the secondary terminals. It causes saturation of the transformer with magnetic fields and increased of internal heat resulting from eddy currents and Magnetic retardation. All these factors cause the explosion of the transformer and porcelain has been broken into small parts that be represented projectiles that affect individuals and equipment.

Previous efforts and research have been made in the field of CTs. Moisture and marine pollutants have an impact on the safety of the current transformer, so it must be removed from the body of the transformer to protect it from damage [1]. The problems faced by the transformer were analyzed during design, manufacturing and maintenance. An alternative program was developed for the traditional model Production Management System. It is a program to assess and analyze the risks and is interested in reducing the cost of risk [2]. Optical CT is non-conventional method which is characterized by the following; used in large power station, high accurate, improved operational performance of CT and benefits for revenue metering application, but it is complex and expensive [3]. Thermal detection was used as an early warning of faults and disaster reduction [4]. The fault current affects the electrical insulation of the transformer; repeated faults increase the value of the DF [5]. The current transformer is affected by capacitive current winding and phase angle. Calibration was performed to address error under operating conditions at values 100 kV and 2000A [6].

The aim of this research is to improve the electrical insulation properties of the current transformer using nanotechnology. It revolutionized this century because it's small size, ease of preparation, change in material properties and low cost. The NPs have many types that are used electrical equipment like (Fe₃O₄, Al₂O₃ and TiO₂). In this work titanium oxide is used to produce nano-oil, the maintenance of CT is developed by using nano oil. The research organized as follows; First, Electrical insulation tests were performed for an old CT. It was exited from service due to it is not valid and for fear of exploding. Second, the nano oil was prepared by treatment the old transformer oil after that, the break down voltage (BDV) test was performed to confirm

the validity of the nano oil before using it in CT again. Third, The CT was filled with nano oil and the tests were repeated again. Fourth, Results were recorded in both cases and worked of statistical analysis. There was a significant difference, Shows the importance of nanotechnology in the treatment.

2 Experimental Work

2.1 Insulation tests for the old CT

The experiment was operated for CT in transformers substation that is shown in figure 1, the specifications are shown in APPENDIX. The reasons for dismissal from service aging and low electrical insulation value. So it is became a threat to the safety of personnel and equipment, It has been replaced by a new one with the same specifications. In this experiment, three basic tests were performed, as follows: BDV, Dissipation Factor (DF) and Insulation Resistance (IR). To ensure the effectiveness of the new maintenance, Tests were performed before and after treatment and through statistical analysis, the significant differences were clarified.



Figure 1: The current transformer was used.

2.1.1 Break Down Voltage Test

This test reveals the validity of the oil if the BDV value is low. this is evidence of internal problems and it can only be used after re-refining. If the insulation is high, this means indicates the safety of the oil. This test is a quick,

inexpensive detection of the oil condition and portable can be used in stations. In rated voltage 66 kV the result shall be satisfactory, if the BDV of the test apparatus is not broken at less than 50 kV / 2.5 mm. It was Invalid and indicated there are impurities or moisture. In this test, (BAUR) oil tester model (DPA 75C) is used for testing the CT.

2.1.2 Dissipation Factor Test

The DF is called $\tan(\delta)$ test; this test shows the leakage of current in oil. The dissipation factor device was used in this Test which is (BIDDLE). It has two units one of them for control and other for injected the power, the rated of voltage injected 10 kV, apparent power 1 KVA and current 0.1 A. The angle between the voltage and current are measured through the insulation. If the angle between the voltage and current is (θ) , therefore the completed angle is (δ) that very small value. Whenever small $\tan(\delta)$ was better insulation and increased is bad insulation. The typical $\tan(\delta)$ value shall not exceed 0.5% at 20 ° C. Connectors to test the CT are shown in figure 2.

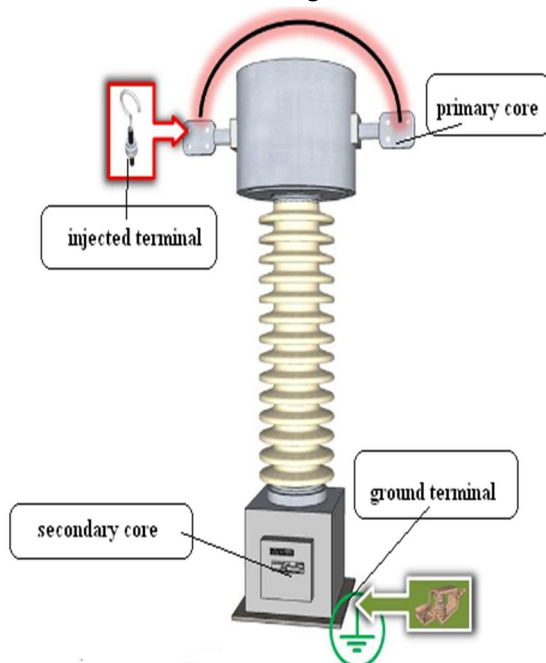


Figure 2: DF test for CT

2.1.3 Insulation Resistance Test

This test used to determine the condition of electrical equipment insulation. It's useful for providing an indication of deteriorating trends in

insulation system. The IR device was used in this experiment (CHAUVIN ARNOUX) device. IR test on CT are performed at 5000VDC for high voltage equipments. The test was performed as follows:-

1. Primary to secondary: Checks the condition of the insulation between high to low.
2. Primary to ground: Checks the condition of the insulation between high to ground.
3. Secondary to ground: Checks the condition of the insulation between low to ground.

2.2 Preparing the nano oil for the CT

Nano oil is a mixture of transformer oils and NPs; it was added in a certain way. There are several types of transformer oils. Diala oil D is used in CT that is conformed to specification IEC 60296. There are many nanoparticles used in the field of insulating oils, in this experiment titanium oxide (TiO₂) was used. Titanium oxide is not a super conductor. If the conductor is 100% for copper, the conductivity is 3.1% of TiO₂. It is increased the insulation efficiency of the electrical equipment's. The steps of preparation the nano oil are summarized as follow in Figure 3.

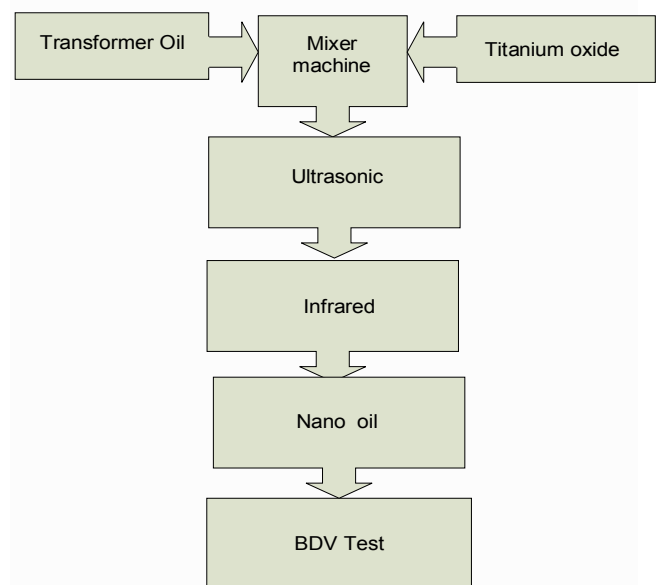


Figure 3: Steps to prepare nano-oil

TiO₂ is obtained from (Alpha Chemika) company as a powder with a particle size below 100 nm , a

purity 99.5% and a relative density of 4.26 g/ cm³. In order to melt TiO₂ in the oil must be used high frequency waves. The ultrasound frequency is used at 65 kHz and the waves are concentrated on oil for two hours. So, TiO₂ was melted into the oil. Despite the benefits of ultrasound, it caused the appearance of moisture and dissolved gases in the oil. To treat these problems, thermal energy must be used. The infrared is used for heating the oil, removing moisture and Purifying the oil from dissolved gases. The oil temperature ranges between (50 - 55 ° C). It is not exceed 60 ° C because this increase causes oil aging and deterioration. The BDV test was performed, to ensure improved insulation properties of nano-oil. The current transformer is filled with nano oil and electrical insulation tests are repeated.

3 Results and Discussion

3.1 Break Down Voltage Results

The test was repeated 6 times, and between each test to another test is 5 to 10 minutes, To disperse negative charges between electrodes and then calculating the mean value of the all values. It was done for old oil and nano oil. The average values were 39.5kV and 52.2 kV respectively. BDV for IEC 60156 must not be less than 50 kV at operated voltage 66 kV. So the test was done for new oil and the average values were 55kv. The new oil was considered a standard value for comparing values that shown in figure 4.

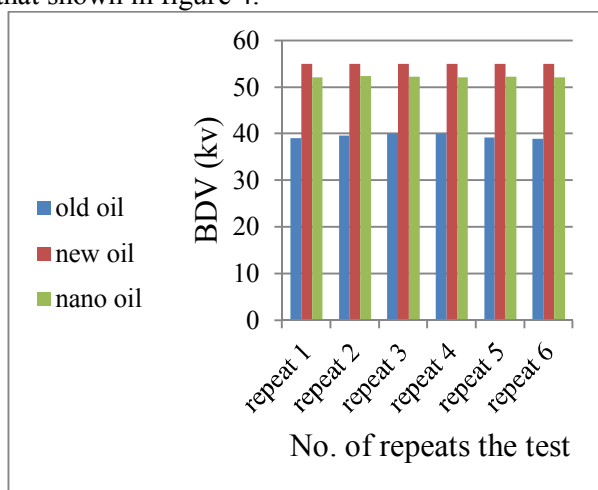


Figure 4: The BDV measurement for CT.

From the graph, the approximate value of new oil and nano oil is shown. To illustrate the improvement, the t-test was used. T-test is one of the most important statistical tests and most commonly used in research studies. It is used to

detect the presence of statistical significance between two samples. The test was performed using the excel program, between two sample assuming equal variances, the results are shown in Table 1.

Table 1: T-test of BDV for CT.

T-Test: Two-Sample Assuming Equal Variances				
	comparison 1		comparison 2	
	nano oil	new oil	old oil	new oil
Mean	52.23333	55	39.51667	55
Variance	0.014667	0	0.229667	0
Observations	6	6	6	6
Pooled Variance	0.007333		0.114833	
Hypothesized Mean Difference	0		0	
df	10		10	
t Stat	-55.9586		-79.1391	
P(T<=t) one-tail	4.03E-14		1.27E-15	
t Critical one-tail	1.812461		1.812461	
P(T<=t) two-tail	8.06E-14		2.54E-15	
t Critical two-tail	2.228139		2.228139	

Table 1 is shown near t state of the nano oil to the new oil, at a confidence level of 95%.The spacing of the t state between the old oil and the new oil is shown. So the absolute and relative errors were calculated.

The absolute error (E):-

$$E = |x_i - \mu| \tag{1}$$

Where:-

μ : The exact value

x_i : The measured value

The relative error (R):-

$$R = \frac{E}{\mu} * 100 \quad (2)$$

The results of absolute and relative error were shown in table 2.

Table 2: E & R results of BDV for CT

	Old oil	Nano oil
E	15.5	2.8
R %	28.18	5.091

From the table it is clear that the relative error of the old oil was the 28.18%. While for nano oil 5.091% and shows credibility. This confirms the importance of using nanoparticles.

3.2 Dissipation Factor Results

The values for DF were taken at different voltage values Ranging from 1 to 5 kV. The relationship between DF was made when using nano oil and old oil. It turned out a marked improvement in values in figure 5. The low value of DF is a clear indicator of improved insulation properties.

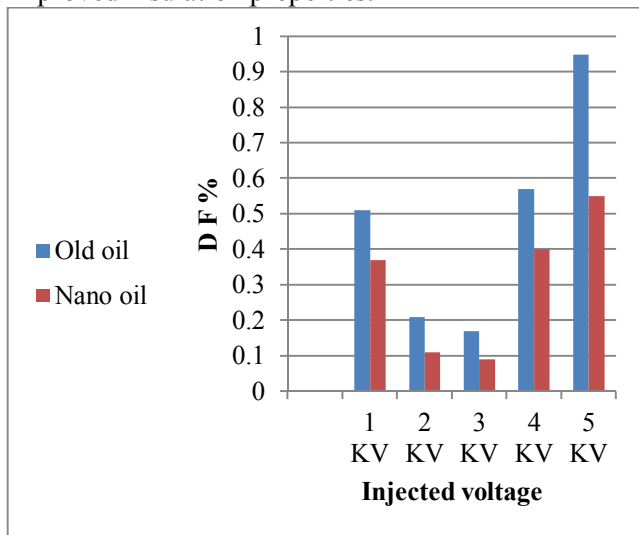


Figure 5: The DF measurement for CT.

From IEC 61620 standard, the value must not exceed 0.5%. So it was taken as a standard value to calculate the standard deviation and error ratio. The values were calculated with excel program in the table 3.

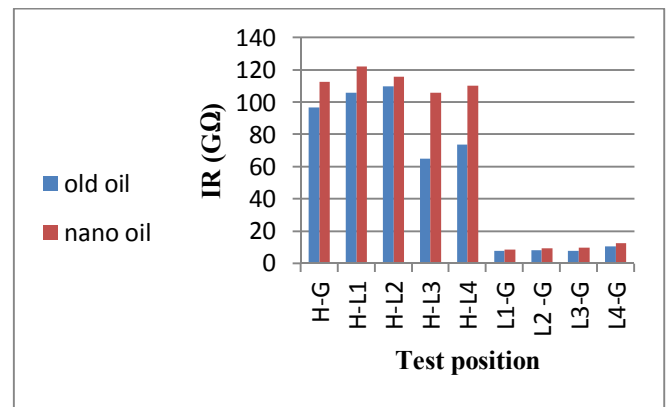
Table 3: the standard deviation and error ratio results for CT

	Old oil	Nano oil
E	0.45	0.05
R %	90	10
S	0.225	0.025

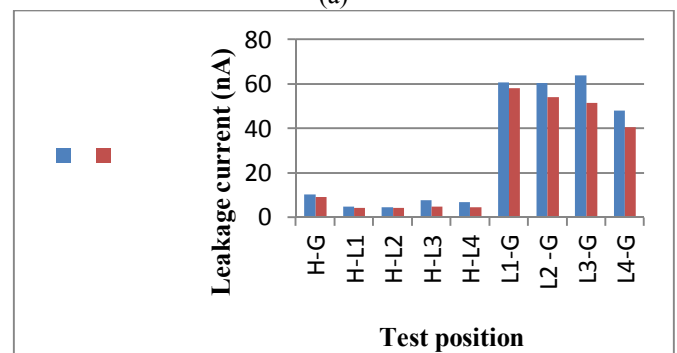
Thus, it is clear that the error rate is 10% when using the nano oil while error rate is 90% when using the old oil. Also the coefficient of the common deviation of nano oil is much lower than the old oil.

3.3 Insulation Resistance Results

The test was performed before and after treatment as shown in figure 6. The insulation between the current transformer windings and windings to ground was checked for dielectric strength. Insulation tests on current transformers are usually performed at 1000VDC. The process of treatment led to an increase in the value of electrical insulation and a decrease in leakage current.



(a)



(b)

Figure 6: (a) The IR measurement for CT. (b) The Leakage current measurement for CT.

Results show the improvement in leakage current and IR values when using nano-oil. Transformers oils were contained of carbon and hydrogen. When an electric arc occurs inside the oil, it is extinguished the spark, but with frequent recurrence it is decomposition. Carbon is semiconductor material, in the normal state is isolated but, when the heat was increased the insulation is broken. The basic idea, when electromagnetic waves such as infrared radiation are exposed to the carbon atoms and the titanium oxide, there is attraction between them, the nano-particles work trap carbon, after it was free into oil. This process is shown in figure 7. Thereby increasing the electrical insulation of oil.

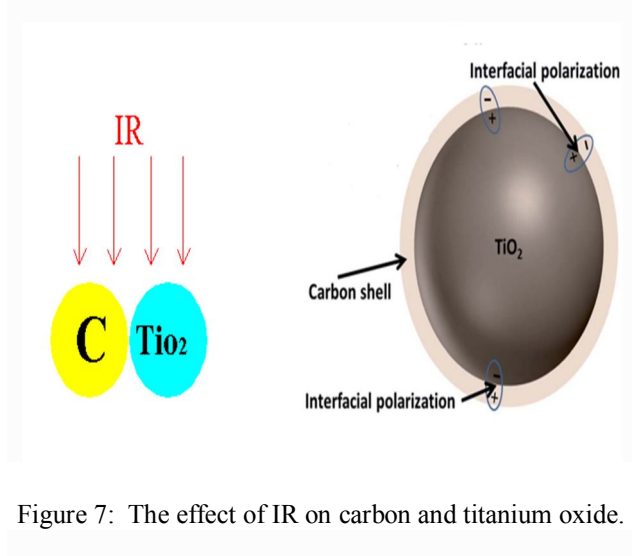


Figure 7: The effect of IR on carbon and titanium oxide.

4 Conclusion and Recommendation

4.1 Conclusion

- Improve the conventional maintenance of the CT, where the basic problems were analyzed, which cause deterioration.
- Using nanotechnology to trap carbon atoms inside oil, to minimize its problems.
- Improving the BDV leads to a higher efficiency of the CT.
- Improve the isolation properties of the CT, Affects the results of IR and DF.

4.2 Recommendation

This CT is out of service due to the high value of DF. After this treatment, it can return to service again. Because the electrical insulation values have improved. Therefore, it is necessary to do the following:

- Perform electrical insulation tests for the CT annually instead of every 3 years.

- CTs subjected to faults must be tested every six months.
- Heavy CT maintenance is required every 5 years, where the oil is discharged and treated with nanoparticles, the tests are then carried out to ensure the success of the maintenance process.

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