purity 99.5% and a relative density of 4.26 g/ cm3. In order to melt TiO_2 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, TiO_2 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.

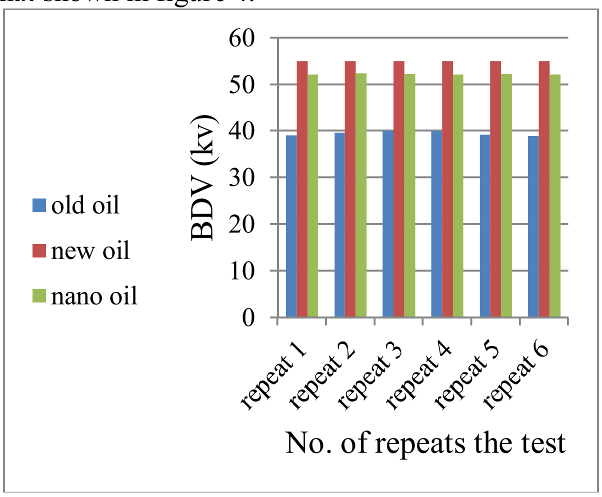


Figure 4: The BDV measurement for CT.

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):-

$$E = |x_i - \mu| \quad (1)$$

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.

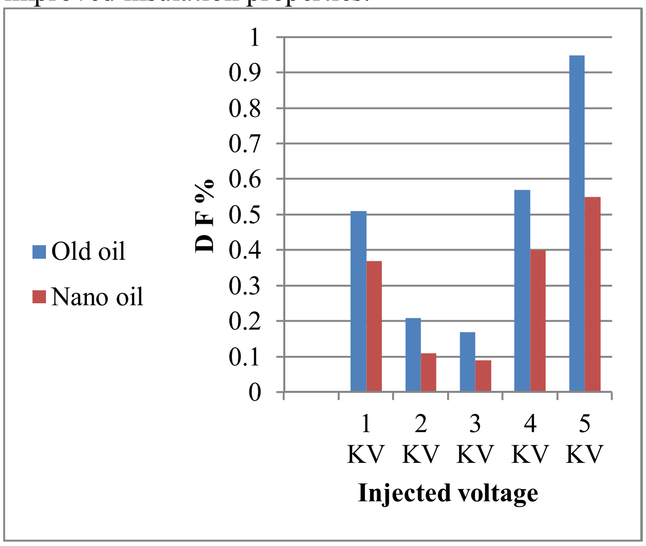


Figure 5: The DF measurement for CT.

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.

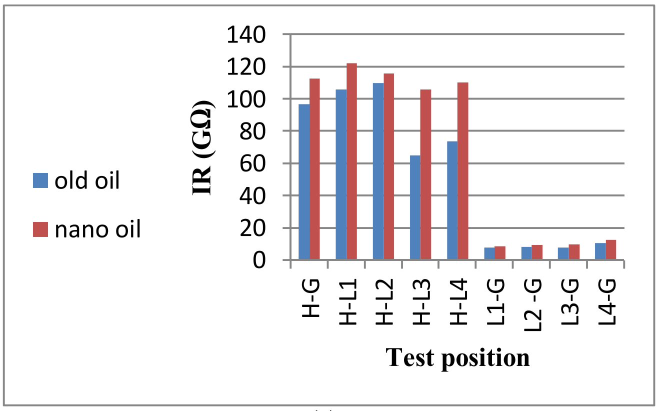
Table 3: the standard deviation and error ratio results for CT

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

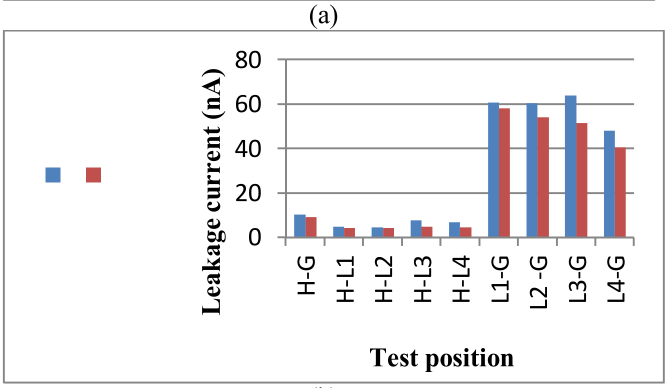
Thus, it is clear that the error rate is 10% when using the nano oil while error rate is 90% when using the old oil. Also the coefficient of the common deviation of nano oil is much lower than the old oil.

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.

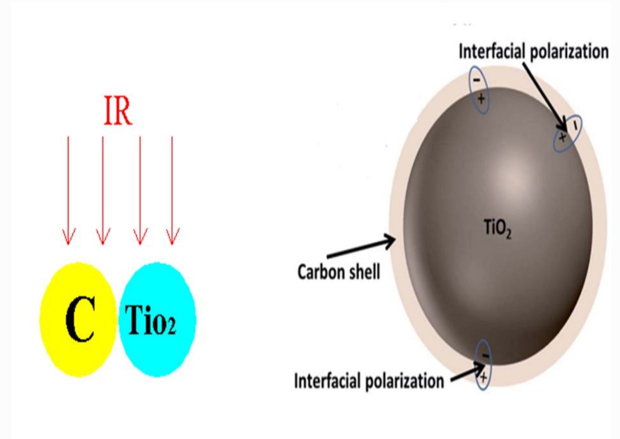


Figure 7: The effect of IR on carbon and titanium oxide.

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.

References:

1. Reyes et al., "Abnormal Failure Rate on High Voltage Current Transformers Affected by Environmental Conditions," Conference Record of the IEEE International Symposium on Electrical Insulation, Vancouver, BC, 2008, pp.247-251.
2. L. Hong, W. Zhili and W. Xinwei, "Transformer risk assessment model under condition based maintenance," IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), Chengdu, 2017,pp.1-5.
3. E. So, R. Arseneau, D. Bennett and M. Frigault, "A current-comparator-based system for calibrating high voltage conventional and non-conventional current transformers under actual operating conditions of high voltage and distorted current waveforms up to 100 kV and 2000 A," *CPEM*, Daejeon,2010, pp. 561-562.
4. E. Mechkov, "Application of infrared thermography technique in transformers maintenance in distribution network," 15th International Conference on Electrical Machines, Drives and Power Systems (ELMA), Sofia,2017 pp.354-357.
5. F. Mustafa, S. Shaulagara and M. Ihsan, "The through fault current effect of 150/20 kV transformer to its insulation resistance and Tan Delta test in PT. PLN (Persero) TJBB APP Durikosambi," International Conference on High Voltage Engineering and Power Systems (ICHVEPS), Sanur, 2017,pp. 193-197.
6. B. Djokic and H. Parks, "Development of a system for the calibration of digital bridges for non-conventional instrument transformers," Conference on Precision Electromagnetic Measurements (CPEM2016),2016, Ottawa, ON, pp.1-2.
7. A. A. Abdul-Aleem, A. M. Abd-Elhady and M. A. Izzularab, "Experimental evaluation of creeping flashover at nanofilled oil /pressboard interface," Nineteenth International Middle East Power SystemsConference (MEPCON), Cairo,2017, pp.695-701.
8. S. S. Dessouky, S. A. M. Abdelwahab and M. Shaban, "Effect of titanium oxide nanoparticles on breakdown strength of transformer oil," Nineteenth International Middle East Power

Systems Conference (MEPCON), Cairo,2017, pp.538-542.

9. M. Rafiq, Y. Lv, C. Li and Kai Yi, "Effect of different nanoparticle types on breakdown strength of transformer oil," IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP), Toronto,2016, pp.436-440.