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DIAGNOSIS OF OLTC USING DGA AND STATIC WINDING RESISTANCE TEST

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***Abstract*— On Load Tap Changer (OLTC) failure occurs is due to the insulation degradation and contacts failure inside it. Other than that, contacts wear influences the OLTC performances. The worn contacts will cause hotspots in the OLTC tank and cause the insulating oil to degrade faster. As a result, this will lead to the damage of complete transformer unit. Thus, the research work that has been carried out applied the Dissolved Gas Analysis (DGA) via latest Duval Triangle method during the diagnosis of OLTC rated at 33/11kV, 30MVA at the first stage to provide early indication of OLTC's breakdown. The Static Winding Resistance Test is then applied at the second stage to figure out any increase of contact resistances for all phases. In addition, it is expected to have a relationship between both results. The results showed that it was proven that by performing DGA via latest Duval Triangle method, the early indication of OLTC's breakdown can be obtained. Besides, this paper revealed that the Static Winding Resistance Test was capable to provide any sign of bad contacts in fixed condition as well as looses connections.**

***Keywords*—Contact resistance, Dissolved Gas Analysis (DGA), Duval Triangle Method, OLTC testing, Static Winding Resistance Test.**

I. INTRODUCTION

Power transformers play a vital role in power systems. The existence of a tap changer is being considered as the only moving element inside a power transformer. The mechanism of transforming the output voltage by selecting number of turns of the winding is done via tap changer [1].

Generally, tap changer are divided into two types which are on load tap changer (OLTC) and off load tap changer. OLTC is used to ensure that the secondary voltage is in the accepted and reasonable range by selecting a correct tap during loaded condition without interrupting the load current [1]. The reason is any interruption of the load current could cause failure in a power transformer.

Most power transformers studies indicated that the main cause of power transformers failures is the OLTC [1,2]. The OLTC results in higher failure rates compared to other electrical components since their mechanical parts are usually in operation as compared to others. Furthermore, their failures have effected on the damage of complete transformer unit. Thus, condition based maintenance should be a better option to observe the condition of the OLTC [1].

In this paper, the diagnosis of the OLTC is done by 2 different stages. Firstly, Dissolved Gas Analysis (DGA) data obtained from OLTC are analyzed using latest Duval Triangle method. Lastly, the results that obtained from DGA via latest Duval Triangle method will be compared with the results carried out from Static Winding Resistance Test to validate the results that was obtained from DGA.

II. DGA ON OLTC'S FAULT DETECTION VIA DUVAL TRIANGLE METHOD

The fault detection of power transformer's OLTC is done mainly based on the results of the DGA interpretation. The identification of various faults like electrical and thermal faults can be proceed through DGA as this is the most efficient tool to be used. Various interpretation method of DGA existed [3-6]. One of the most frequently used DGA methods is Duval Triangle for LTC of oil type transformers [7].

This diagnostic method is use for oil insulated high voltage equipment mainly transformer based on the use of three hydrocarbon gases which are methane (CH_4), ethylene (C_2H_4) and acetylene (C_2H_2) that corresponding to the increasing energy levels of gas formation in transformers in service.

III. STATIC WINDING RESISTANCE TEST

The Static Winding Resistance Test will be done to OLTC by using a filtered continuous DC current injection and at the same time high data sampling by using 16 bit Analogue Digital Converter (ADC). This device is used to capture the rate of current changes with a high resolution of the time measurement up to 0.1ms, the details operation of the transition time for the diverter switch, transition resistor conditions and tap selector switch movements.

This test equipment is capable to inject a DC current from as smaller as 5mA up to maximum of 60A. Furthermore, the resistance measuring range is between 0.1µΩ up to 2kΩ. This test is done to all the three phases (Red, Yellow and Blue). Firstly, the test will start with Dynamic Resistance Pre-Check Test and ended with the Static Winding Resistance Test. The specifications of the equipment that will be used are shown in Table 1.

Table 1. Test Equipment Specifications.

Test current	5mA DC maximum up to 60A DC (programmable)
Measuring range	0.1μΩ up to 2kΩ
Maximum measuring resolution	0.1ms time base, 16 bit analogue to digital converter
Testing mode available	Static and dynamic winding resistance in a single test. Continues test capability for OLTC operation
Dynamic Test for On Load Tap Changer diagnosis	Performs High Resolution Dynamic Resistance Measurement to obtain automatically dynamic resistance graph of the OLTC, a diverter transition time, tap selector switch condition, percentage of current ripple and each tap position
Ripple detection	May vary from 1% up to 9.9 %

A. Dynamic Resistance Pre-Test Check

The important of doing this test is to ensure that the current is stabilized before proceed with Static Winding Resistance Test to prevent any errors during the whole test. The estimation of the stabilizing time for the injected current will be obtained from this test.

B. Static Winding Resistance Test

Static Winding Resistance Test occurred after the measurement has stabilized by measuring the DC voltage drop across the winding by injected a DC current of 1% of the current at nominal voltage. The resistance is measured on all taps of a tapped winding to ensure that the OLTC does not open. The diagnosis of OLTC via Static Winding Resistance Test is divided into three different steps.

Firstly, the results of a Static Winding Resistance test will be recorded in an EXCEL spreadsheets format automatically without be needing third party conversion software. The values of contact resistance for all the taps will be compared in term of phase to phase deviations (in percentage unit). This is to check whether this OLTC facing an increased resistance of contacts. Thus, the higher values will results in the increased resistance of contacts.

Furthermore, the comparison of phase to phase deviations (in percentage unit) is then compared to the IEEE Std. 62-1995 in which it must be less than 5% of differences [8].

Lastly, the winding resistance value is plotted against the tap number manually via EXCEL spreadsheets. The graph is expected to be a linear relationship.

The Static Winding Resistance Test purposely to reveal for the bad contacts in fixed conditions and loose connections. As a result, through this test, the winding resistance is measured in the field to identify shorted turns, poor joints, high contact resistance connections or contacts and open circuits of the transformer windings.

IV. RESULTS AND DISCUSSIONS

The fault coordination of the OLTC after the faults plotting process via Duval Triangle has been done is shown in Fig. 1. As a result, the diagnosis shows that the condition of this OLTC is at “X3”. Table 2 shows the summary of the OLTC’s fault indication. Hence, this OLTC is considered to have a light coking or increased resistance of contacts or severe arcing.

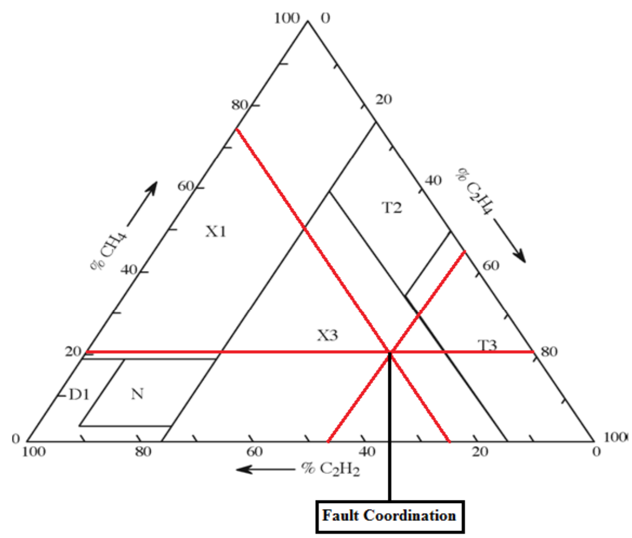

Figure 1. Fault coordination of OLTC using Duval Triangle.

Table 2. Summary of the OLTC fault indication using Duval Triangle

Zone	Identification	Recommended Actions
X3	Fault T3 or T2 in progress (mostly) with light coking or increased resistance of contacts. Or severe arcing	Test or inspect the OLTC for signs of light coking or resistance of contacts or of severe arcing

According to Table 2, the OLTC has faced a light coking or increased resistance of contacts or severe arcing. According to Duval Recommended Actions (Table 2), this OLTC needed to be inspected due to the occurrence signs of light coking or resistance of contacts or of severe arcing. However, DGA itself is not firm yet to point out the exact location of the faults existing inside of the OLTC. Thus, Static Winding Resistance Test has been done based to the OLTC to support the results obtained from DGA.

A. Dynamic Contact Resistance Pre-Check Test

The results of Dynamic contact resistance pre-check test is to ensure that this transformer is fully stabilized before any testing is done. Fig. 2 shows that the injected current prior to the test stabilized after 20s at 105mΩ. Thus, this is confirmed that the waiting time with respect to the initial resistance should be approximately at 105mΩ and 15-25s respectively.

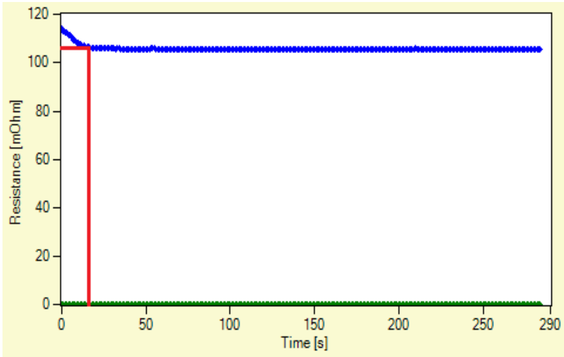

Figure 2. Pre-Check Test before the Measurement

B. Static Winding Resistance Test

Through Static Winding Resistance Test, the contact resistance values are compared phase to phase deviations (Red, Yellow and Blue) for tap up operations.

According to Table 3, red phase faced the highest values of resistance comparison at all tap positions with the range of 0.21% to 4.93%. This followed by blue phase in which the ranges of their resistance comparison are from 0% to 4.6%. The yellow phase is observed to have the lowest values of resistance comparison with the range of -0.77% to 0.13%. With the high values of resistance at both red and blue phases, it can be concluded that this OLTC faced a high values of contact resistance. Thus, Table 3 revealed the results that were carried out by DGA (Table 2), where this OLTC faced an increased resistance of contacts.

Further analysis was done to this OLTC to compare the resistance values with IEEE Std. 62-1995 [8]. By means of Table 3, the box will turn into red color s if only any of the resistance comparison values are more than 5%. However, all of the boxes remained the same (Table 3). Thus, it can be concluded that the contact resistance values are within the acceptable deviation although some of the values are high with all of the resistance values are less than 5% of differences according to IEEE Std. 62-1995 [8].

Table 3. Resistance Comparison For All Phases (Tap-Up Operation)

Tap Positions	1U-1V (Red Phase)	1V-1W (Yellow Phase)	1U-1W (Blue Phase)
1	3.21	-0.09	3.13
2	0.74	-0.10	0.64
3	4.86	-0.28	4.60
4	3.34	-0.65	2.71
5	2.72	-0.54	2.20
6	1.68	0.13	1.80
7	0.99	-0.35	0.65
8	0.21	-0.11	0.10
9	2.49	-0.24	2.25
10	1.12	-0.77	0.35
11	4.93	-0.40	4.55
12	2.78	-0.42	2.37
13	3.82	-0.07	3.75
14	1.40	-0.45	0.96
15	0.43	-0.05	0.37
16	0.24	-0.25	0.00
17	0.23	-0.03	0.21

Finally, the static resistance graphs were plotted for tap up operation (Fig. 3). Theoretically, plotting the winding resistance against the tap number, should give a linear relationship of "V-Shape" for a healthy tap changer. According to Fig. 3, the 1V-1W (yellow phase) and 1U-1W (blue phase) were in a linear relationship. However, the 1U-1V (red phase) was not in a linear relationship. This revealed that 1U-1V (red phase) are concluded to be faulty.

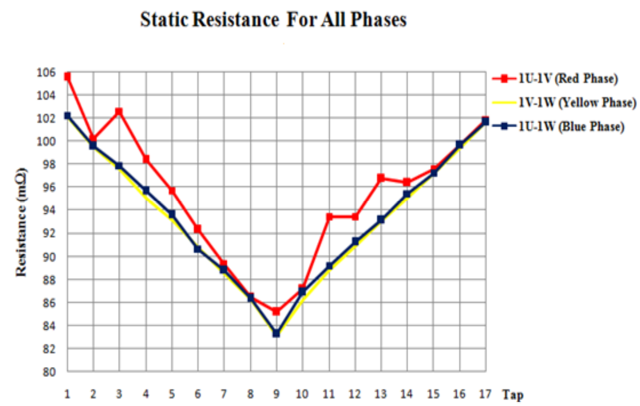

Figure 3. Static resistance graphs for all phases (tap-up operation)

V. CONCLUSION

Ageing transformers require regular checks to prolong their lifetime. Consequently, it is crucial to perform meaningful maintenance to avoid any faults resulting in total failures of OLTC. The findings in this paper suited the aims of this project.

One of them is to provide a better understanding on OLTC diagnosis based on DGA via latest Duval Triangle method and Static Winding Resistance Test. Moreover, this paper revealed that the results obtained from DGA via latest Duval Triangle method were similar to the findings obtained from Static Winding Resistance Test. Furthermore, it was proven that by performing DGA via latest Duval Triangle method, the early indication of OLTC's breakdown can be obtained. Besides, this paper revealed that the Static Winding Resistance Test was capable to validate the results obtained from the DGA

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