Study on the Transformer Oil Filtration Process

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Abstract—**The study was carried out on transformer filtration at Janamanjung Power Plant 700MW. The Filtration process offers a practical, proven and economical method to purify the oil and use it again for high voltage equipment. Filtration of insulating oil is the process of removing moisture, dissolved combustible gas and particular matter as determine by oil transformers test. Test of moisture content, dielectric breakdown, interfacial tension and dissolved gas analysis on the transformer oil were studied to know the time of purifying of changing it. After performing the tests, the oil can classified as reusable with minor reconditioning or disposable and reduces downtime, minimizes the chance of sudden failure and thus allows optimum use of the transformer.**

Keywords-Filtration process; oil insulating; oil test

I. INTRODUCTION

Every company dealing with oil insulated high voltage equipment like power transformer, high voltage switchgear, turbines and etc share the problem of change or disposal of contaminated oils Maintenance and Asset Management are becoming increasingly important [1]. The aim of filtration is to reduce the costs for replacement and repair and to increase the lifetime of your capital goods. Also unexpected breakdowns should be avoided under all circumstances [2]. Beside the early determination of possible malfunctions a very important aspect is the reduction of maintenance and repair costs. High reliability is equal to an increase in efficiency and profitability.

Insulation Oil is considered to be one of the weakest points on a transformer. This perception must be considered in any maintenance concept. The lifetime of transformer oil is not equal to the lifetime of a transformer itself [2]. So, the filtration process is one of the ways to improve the oil quality.

The insulation oil will weak cause of oxygen in the air, combined with the heat developed during normal operation, will result in the formation of acids and sludge in the oil [3]. This sludge will settle on the horizontal parts of the windings and at the bottom of the tank and interferes with the normal circulation of the oil and its abilitv to dissipate heat. The sludge can also reduce the flash-over value of the insulating surface. Moisture is the most dangerous contaminant of insulating oils [3]. As small as ten parts per million by volume can lower the dielectric strength of the oil.

A sample of insulating oil from a transformer in service can reveal much information about what is taking place inside the transformer. There are three basic enemies to insulating oil - oxidation, contamination and excessive temperature. The following tests can be done,

i) Moisture content

ii) Dielectric breakdown

iii) Interfacial tension

iv) Dissolved gas analysis

A. Moisture Content

One of the most important functions of transformer oil is to provide electrical insulation. Any increase in moisture content can reduce the insulating properties of the oil, which may result in dielectric breakdown [4]. This is of particular importance with fluctuating temperatures because, as the transformer cools down, any dissolved water will become free, resulting in poor insulating power and fluid degradation. In addition, many transformers contain cellulose-based paper used as insulation in the windings. Again, excessive moisture content can result in the breakdown of this paper insulation with a resultant loss in performance.

B. Dielectric Strength

The dielectric strength of transformer oil is defined as the maximum voltage that can be applied across the fluid without electrical breakdown [4]. Because transformer oils are designed to provide electrical insulation under high electrical fields, any significant reduction in the dielectric strength may indicate that the oil is no longer capable of performing this vital function [4]. Some of the things that can result in a reduction in dielectric strength include polar contaminants, such as water, oil degradation by-products and cellulose paper breakdown.

C. Interfacial tension

The interfacial tension tests measure the presence of soluble contaminants and oxidation product [5]. A decreasing value indicated an increase in contaminants and oxidation product within the oil.

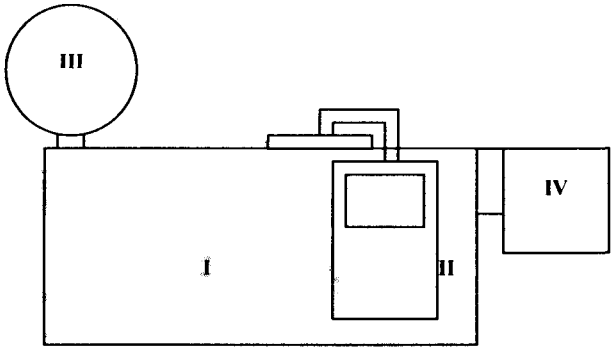
D. Dissolved Gas Analysis (DGA)

Dissolved gas analysis is used to determine the concentrations of certain gases in the oil such as nitrogen, oxygen, carbon monoxide, carbon dioxide, hydrogen, methane, ethane, ethylene and acetylene (ASTM D3612). The concentrations and relative ratios of these gases can be used to diagnose certain operational problems with the transformer, which may or may not be associated with a change in a physical or chemical property of the insulating oil [9]. For example, high levels of carbon monoxide relative to the other gases may indicate thermal breakdown of cellulose paper, while high hydrogen, in conjunction with methane may indicate a corona discharge within the transformer.

Pressure Leak Test a transformer can be checked for pressure leaks by pressurizing the tank and then leaving it alone for several hours. If the pressure drops during the intervening time, or if there are signs of liquid leakage, than a leak is present. Otherwise, the transformer is leakage free.

Commonly, transformer can divided into 4 major compartments as show in figure 1 below.

II. TRANSFORMER COMPARTMENT



I – *Main body (main tank)*
II – *On-load Tap Changer (OLTC)*
III – *Conservator tank*
IV – *Cable Chamber box*

Figure 1. Transformer major compartment

A) Main body

Main body is the largest of oil volume quantity storage in the transformer. In site the main tank, place the HV winding and LV winding [7]. The volume of the oil in the main tank is depends on the size of the Transformer. If the kVA and voltage is bigger, the volumes of oil also increase. For example, autotransformer 240MVA, 275/132kV have around 85,000 liter oil but power transformer 90MVA, 132/3kV have around 45,000 liter oil.

B. On-load tap changer (OLTC)

Moving part of the transformer. OLTC will change the number of tap changer follow the voltage required controlled by automatic voltage relay (AVR) [1]. The movement of part in site of the OLTC compartment will produce carbon and moisture [1]. That is the reason why OLTC compartment will record a lowest reading for dielectric test before filtration.

C. Conservator tank

Use for main body oil storage and furnished with oil level low to make sure the quantity of oil always ¾ tanks. Conservator tank is the highest compartment for the transformer because when the level of oil in main body decreases, we can fill at atmospheric pressure [3].

D. Cable chamber box

Location where the connection of the bushing and outgoing power cable have made.

III. METHODOLOGY

Figure 2 shows a flow chart and procedure of transformer oil filtration process.

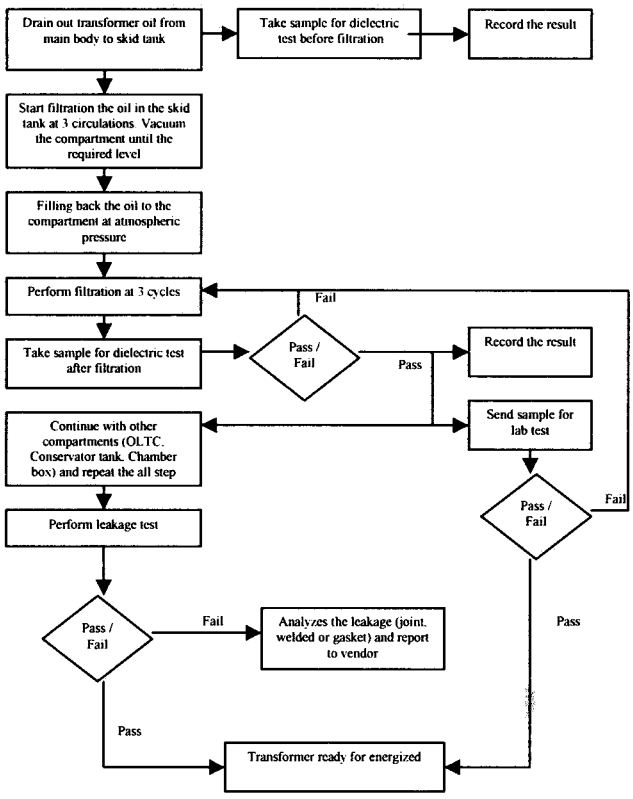


Figure 2. Flow chart for the oil filtration process

This procedure of transformer oil filtration is for 900MVA transformer at Janamanjung Power Plant

3X700MW. The process be perform for four compartment as per below;

i) Oil Filtration of main body.
ii) Oil Filtration of on-load Tap Changer (OLTC).
iii) Oil Filtration of Conservator tank.
iv) Oil Filtration of cable chamber box.
v) Leakage Test (additional)

A. Oil Filtration of main body/OLTC compartment/cable chamber box/Conservator tank (main)

Before start the filtration process, oil sample take from all compartment for perform on-site dielectric test. The result will use as reference for the after filtration. The insulation oil will drain out from the entire compartment into skid tank. Filtration to be perform for the oil in skid tank at least 3 circulation treatments. The filtration equipment used is Sanmi type VSD-10000S. The equipment equipped with heater, degassing chamber and filter. The heaters are use for remove the moisture in the oil with heat the oil. Degassing chamber will isolate particle of carbon, wax and gasses. And the filter will remove the some particulate impurities. Three circulation means the circulating time of the oil. For example, if the compartment have 4000liter oil, so filtration to be perform is 12000liter. The number of liter have be done by the filter machine can be directly read on the flow meter equipped inside the machine. After done the process, all the insulation oil filled back into the all compartment. Filtration 3 circulations again and get a sample to perform on site test dielectric test.

Experimental test are carried out on transformer oil to determine experimentally their electrical, physical and chemical properties. 2 oil samples will take from each compartment. One sample for on site dielectric test and another one sample will send to lab for carried out tests included moisture content, dielectric breakdown, interfacial tension and dissolved gas analysis.

From the result get from on site test and lab test are analyses to make sure the reading as per client requirement. If the result fails, the filtration of that compartment must start again.

Determination of breakdown voltage of each transformer oil sample was carried out according to the IEC 156 testing procedure [6]. Method of dissolved gas analysis (DGA) in transformer is provided in IEC 60599[9].

B. Leakage Test

Pressure Leak Test a transformer can be checked for pressure leaks by pressurizing the tank and then leaving it alone for several hours. If the pressure drops during the intervening time, or if there are signs of liquid leakage, than a leak is present.

IV. Results and Discussion

Experimental test are carried out on transformer oil to clarify experimentally of electrical, physical and chemical properties. The carried out test on the transformer divided for two type. On site test and another one is lab test. For on site test are dielectric test and for lab test included a moisture content, dielectric breakdown, interfacial tension and dissolved gas analysis.

Table 1 shown a result for the before and after filtration and the Figure 3 shown the graph of improvement of dielectric test result for all compartment of transformer.

TABLE 1. ON SITE DIELECTRIC TEST RESULT

No.	Compartment	Before filtration (kV)	After filtration (kV)	TNB requirement (kV)	Status (pass/ fail)
1	Main body	68.2	73.7	60	pass
2	On-load tap changer (OLTC)	52.1	76.5	60	pass
3	Conservator tank	71.1	79.2	60	pass
4	Cable chamber box	62.2	77.5	60	pass

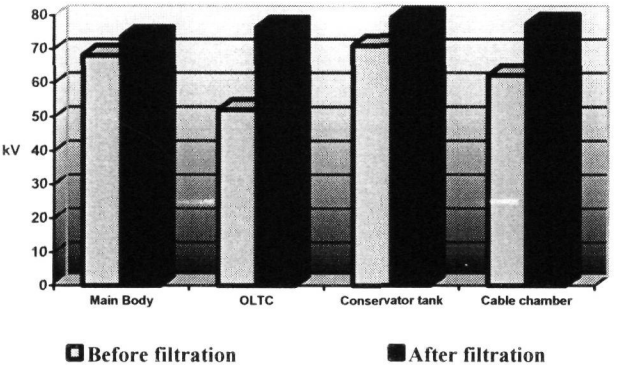


Figure 3. Comparison graph of on site dielectric test

For oil lab test, there are four tests to be performed to all compartments. It is moisture content, dielectric breakdown, interfacial tension and dissolved gas analysis. All the test must pass as per requirement before the transformer ready for energized.

TABLE 2. LAB TEST FOR MAIN BODY

No.	Test	Result	TNB requirement	Status (pass/ fail)
1	Moisture Content (H2O), ppm	6	Max15	Pass
2	Dielectric Breakdown (BDV), kV	93	Min 50	Pass
3	Interfacial Tension (IFT), mN/m	28	Min 22	Pass
4	Dissolved gas analysis (ppm)		Max	
	a) Hydrogen (H2), ppm v/v	8	100	Pass
	b) Oxygen (O2), ppm v/v	7168	NS	Pass
	c) Nitrogen (N2), ppm v/v	36009	NS	Pass
	d) Methane (CH4), ppm v/v	21	120	Pass
	e) Carbon Monoxide(CO)ppm v/v	39	350	Pass
	f) Carbon Dioxide(CO2), ppm v/v	536	2500	Pass
	g) Ethylene (C2H4), ppm v/v	4	50	Pass
	h) Ethane (C2H6), ppm v/v	49	65	Pass
	Total Dissolved combustible Gas, ppm	NIL 121	35 NS	Pass Pass

TABLE 3. LAB TEST FOR ON LOAD TAP CHANGER (OLTC)

No.	Test	Result	TNB requirement	Status (pass/ fail)
1	Moisture Content (H2O), ppm	12	Max15	Pass
2	Dielectric Breakdown (BDV), kV	50	Min 50	Pass
3	Interfacial Tension (IFT), mN/m	33	Min 22	Pass
4	Dissolved gas analysis (ppm)		Max	
	a) Hydrogen (H2), ppm v/v	29	100	Pass
	b) Oxygen (O2), ppm v/v	20746	NS	Pass
	c) Nitrogen (N2), ppm v/v	72253	NS	Pass
	d) Methane (CH4), ppm v/v	4	120	Pass
	e) Carbon Monoxide(CO),ppm v/v	21	350	Pass
	f) Carbon Dioxide(CO2),ppm v/v	116	2500	Pass
	g) Ethylene (C2H4), ppm v/v	9	50	Pass
	h) Ethane (C2H6), ppm v/v	1	65	Pass
	Total Dissolved combustible Gas, ppm	8 72	35 NS	Pass Pass

TABLE 4. OLAB TEST FOR CONSERVATOR TANK

No.	Test	Result	TNB requirement	Status (pass/ fail)
1	Moisture Content (H2O), ppm	8	Max15	Pass
2	Dielectric Breakdown (BDV), kV	100	Min 50	Pass
3	Interfacial Tension (IFT), mN/m	31	Min 22	Pass
4	Dissolved gas analysis (ppm)		Max	
	a) Hydrogen (H2), ppm v/v	1	100	Pass
	b) Oxygen (O2), ppm v/v	3818	NS	Pass
	c) Nitrogen (N2), ppm v/v	16055	NS	Pass
	d) Methane (CH4), ppm v/v	Nil	120	Pass
	e) Carbon Monoxide(CO)ppm v/v	24	350	Pass
	f) Carbon Dioxide(CO2), ppm v/v	349	2500	Pass
	g) Ethylene (C2H4), ppm v/v	2	50	Pass
	h) Ethane (C2H6), ppm v/v	Nil	65	Pass
	Total Dissolved combustible Gas, ppm	Nil 27	35 NS	Pass Pass

TABLE 5. LAB TEST FOR CABLE CHAMBER BOX

No.	Test	Result	TNB requirement	Status (pass/ fail)
1	Moisture Content (H2O), ppm	8	Max15	Pass
2	Dielectric Breakdown (BDV), kV	87	Min 50	Pass
3	Interfacial Tension (IFT), mN/m	33	Min 22	Pass
4	Dissolved gas analysis (ppm)		Max	
	a) Hydrogen (H2), ppm v/v	1	100	Pass
	b) Oxygen (O2), ppm v/v	243	NS	Pass
	c) Nitrogen (N2), ppm v/v	1442	NS	Pass
	d) Methane (CH4), ppm v/v	Nil	120	Pass
	e) Carbon Monoxide(CO)ppm v/v	8	350	Pass
	f) Carbon Dioxide (CO2)ppm v/v	68	2500	Pass
	g) Ethylene (C2H4), ppm v/v	2	50	Pass
	h) Ethane (C2H6), ppm v/v	Nil	65	Pass
	Total Dissolved combustible Gas, ppm	Nil 11	35 NS	Pass Pass

The breakdown voltage increases after the filtration process as shown in Table 1 and Figure 3. Results of the dielectric test before filtration are low due to oxidization and contamination. Contamination commonly found in transformer oil includes water and particulate. These contaminants will reduce the insulating quality of transformer oil.

The decreasing in the breakdown voltage because of th long period in service increases some particulate impurities, this will increase the moisture and the oil will become non homogeneous. Consequently, it will decrease the transformer oil resistance, which also will decrease the maximum value of the breakdown voltage of the transformer oil. The arc discharges and intensive localized of the liquid produce particles of carbon, wax and gases such as carbon monoxide, carbon dioxide, acetylene and the acidic products due to oxidation and discharges attack the solid insulation, iron and copper in the liquid, which lead to lowering electric strength. Table 2, 3, 4 and 5 shown a result of the lab test from main body, OLTC, conservator tank and cable chamber box. All the results must be pass as per client requirement.

TABLE 6. TRANSFORMER LEAKAGE TEST

Medium use	Time	Pressure at start kg/psi (mbar)	Pressure at finish kg/psi (mbar)
Nitrogen (N2)	0900	0.31	
Nitrogen (N2)	1000	0.31	0.31
Nitrogen (N2)	1100	0.31	0.31
Nitrogen (N2)	1200	0.31	0.31
Nitrogen (N2)	1300	0.31	0.31
Nitrogen (N2)	1400	0.31	0.31
Nitrogen (N2)	1500	0.31	0.31
Nitrogen (N2)	1600	0.31	0.31
Nitrogen (N2)	1700	0.31	0.31
Nitrogen (N2)	1800	0.31	0.31
Nitrogen (N2)	1900	0.31	0.31
Nitrogen (N2)	2000	0.31	0.31
Nitrogen (N2)	2100	0.31	0.31
Nitrogen (N2)	2200	0.31	0.31
Nitrogen (N2)	2300	0.31	0.31
Nitrogen (N2)	2400	0.31	0.31
Nitrogen (N2)	0100	0.31	0.31
Nitrogen (N2)	0200	0.31	0.31
Nitrogen (N2)	0300	0.31	0.31
Nitrogen (N2)	0400	0.31	0.31
Nitrogen (N2)	0500	0.31	0.31
Nitrogen (N2)	0600	0.31	0.31
Nitrogen (N2)	0700	0.31	0.31
Nitrogen (N2)	0800	0.31	0.31
Nitrogen (N2)	0900	0.31	0.31

From the Table 6 above, the reading of the pressure are continuously constant for 24hours. The transformers are leakage free because if the pressure drops during the intervening time, or if there are signs of liquid leakage, than a leak is present.

To prove the filtration process are more economical than change the new insulation oil, the result taking 1 unit 900MVA transformer at Janamanjung Power Plant as reference. The transformer has total 95,000 liter insulation oil. The comparison is between market price of filtration services by contractor in Malaysia and largest supplier insulation oil in Malaysia, Hyrax Malaysia Sdn Bhd. The result is shown on Table 7.

TABLE 7. PRICE COMPARISON BETWEEN OIL FILTRATION SERVICES AND CHANGE NEW INSULATION OIL

No.	Description	Unit Price (RM)	Total Price (RM)
1.	Filtration services	Lump sum for one unit transformer	25,000.00
2.	New insulation oil Type: Hyrax Hypertrans	6.00 per liter	57,000.00

From the Table 7, proved that the costs for filtration process are more economical than change the new insulation oil. The differences are RM22, 000.00. Another advantages is the filtration process will remove the moisture and gas in the transformer winding but changing the oil only can get new oil but the moisture still in the winding.

This transformer oil filtration showed a good performance to the insulating oil after filtration process where the result achieve the expected and client requirement but there are still consideration works need to be improve;

i) Used a more powerful machine for the filtration. When use a bigger machine, process of filtration at skid tank can be abolished and directly filter in the transformer. This will reduce the manpower cost.

ii) The reason of generation gases is not only the fault inside the transformer, but also the increasing in temperature in the transformer oil due to the cooling lack. So, make maintenance include the transformer cooling system.

V. CONCLUSIONS

Although transformer oil testing is important, the results will be worthless if do not know how to interpret them. All result above lists the recommended threshold levels to deem oil satisfactory for continued service. Oil that does not meet the recommended levels should be reconditioned, reclaimed, or disposed of, depending on the test.

From the results, it is shown that there are improvements of oil quality after the filtration process. The used oil can be clean without change with new oil. So, the filtration process offers a practical, proven and economical method to purify the oil and use it again. The transformer oil only can be changed in the following cases; a) used transformer oil and high total combustible gases. b) Both of total acidity and breakdown voltage are out of allowable standard ranges. c) The physical tests are out of allowable ranges.

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