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# The Nynas Nitro Libra Oil Testing as an Isolator on the 150 kV Transformer Using Colour, Water Content, and Breakdown Voltage Testing Method in Bantul Substation

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**Abstract** – *In the system of electricity power, either thermal or electric failure often takes place. In order to prevent such failure, isolator testing towards the power transformer is needed. A mineral oil Nynas Nitro Libra was used as the research subject, in which it was compared to the other oil types, involving new oil, in-use oil, and used crude oil. The method used was testing throughout the colour, water content, and breakdown voltage. Colour testing was conducted by comparing between used oil and typical oil, whereas water content was conducted by mixing chemical ingredients which were Solvent Xylol and toluene, followed by 100°C heating process within 3 hours and condenser cooling down until the moisture dropped down the trap, finished by 6 times breakdown voltage test through environment temperature. The testing result shows that crude oil indicates D 8,0 (black colour), with moisture content TRACE (0.2%) which is 4 ppm. The value of 6-time breakdown voltage test in the temperature of 22°C indicates: 09.4 kV, 09.1 kV, 09.2 kV, 09.6 kV, 09,5 kV, 12.0 kV with dielectric power 3.92 kV/mm.*

***Keywords****: Isolator oil, Colour, Water Content, Breakdown Voltage, Dielectric Strength*

## I. Introduction

From studies conducted by the US Inspection and Insurance Companies, a 10% failure of power transformers is caused by a reduction in the quality of insulating material and internal failure of overload in high voltage windings caused by the addition of deposits.

The transformer is an electric magnet that is simple, reliable, and efficient for converting alternating current (AC) voltage from one level to another based on the principle of electromagnetic induction of a magnetic field. Transformers generally have several components such as a core made of layered iron, and there are 2 coils, namely a primary coil and a secondary coil. The voltage change used in the transformer depends on the number of ratios of the coil on the primary and secondary sides. "(Abdul Kadir, 1989:1)".

The term power transformer is used to refer to transformers used between generators and distribution circuits, and this is usually rated 500 kVA and above. So in order to get the condition of a 500kVA capacity transformer service that can actually operate it must have an ambient temperature below 40 °C and above -20 °C with a harmonic distor below 0.05 per unit. (James H, 2004: 14-15).

Every operation of the electric power system, especially in the transformer, sometimes occurs a failure phenomenon, both in the form of thermal failure, mechanical failure, or electrical failure. If the failure occurs at any time or in an ongoing manner it will have an impact on decreasing the life of the transformer oil insulation or damage to other parts of the component which can be fatal. If there is a failure, the one that will protect the transformer is the relay-releasing safety on the transformer. Factors that can cause failure are high temperatures, so it requires a cooling system to regulate high temperatures due to various factors when the

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transformer operates. High temperatures can accelerate the decline in life and performance of the transformer.

Based on the IEEE standard, the use of power transformers up to 180,000 hours, equivalent to 20.55 years, whereas according to the IEC standard, the determination of the age of the transformer cannot be determined specifically, because each use of the transformer is different in terms of operation. But according to the IEC standard the transformer can be 30 years old if the transformer operating period is not long.

The quality of insulation can determine the continuity of operating performance on the transformer. One of them is insulating oil. The media used for cooling and insulation is using transformer insulation oil. When there is damage to the insulation system, insulation oil will play a role to dissolve the gas. When the transformer operates, the condition of the transformer oil will expand due to the presence of thermal loads and from the coil. The electricity needs of the community that must be supplied 24 hours make the transformer must work continuously, the use of which exceeds its reasonable limits for very long duration of use will have an impact on dielectric damage, or deterioration of oil quality caused by excessive heating, causing various chemical structure damage and increased dissolved gas in insulating oil.

## II. Insulation Oil

Liquid isolator has 4 functions, namely as insulation in the stressed part, as a transformer cooler, extinguishing arching, and partial discharge and gas solvent. Some reasons for liquid insulators are used (Purwasih, 1998):

1. Liquid insulator has a density of 1000 times compared to solid insulators, so the dielectric strength is higher.
2. Liquids have properties that can fill every existing cavity, then the liquid insulator will fill the gap or room that will be isolated.
3. When the release occurs, the insulator can repair itself.

### *II.1. Function of Isolation Oil*

The high temperature in the transformer gives rise to carbon in transformer oil, because carbon has properties as a conductor and is mixed in oil, so the quality of the transformer oil insulator will decrease. Arching between windings in the transformer can cause burning of paper insulators in the coil of the transformer coil which eventually produces carbon (Krinsi, 1996).

The main functions of transformer oil are:

1. As an insulator, a minimum breakthrough voltage that can function as an insulator is 30 KV.
2. As a cooling medium, when the operating transformer oil will heat up and have a high temperature, then the temperature must be continuously monitored continuously with temperature relay.
3. Arching dampening through cooling properties and insulator properties.
4. Parts which have arching potential should not be passed by gases caused by flammable solvents, the area includes OLTC parts, and loose joints.

### *II.2. Oil Insulation Requirements*

Leave one line space of 10 pts and then give the abstract. Before the body of the abstract and the keywords, the terms ‘Abstract -’ and ‘*Keywords*:’ should come in bold 11 pts, respectively.

Of all the characteristics and rules of using an oil insulator to fulfill its purpose as an insulator (insulator), oil insulators must meet the following requirements (Arismunandar, 2001):

a. Clear, does not contain deposits.
b. Heat type and high conductivity.
c. Low viscosity.
d. Low density and density.
e. Flash point and flash point
f. Low substance content and non-flammable
g. Chemical stability and good gas absorption properties.
h. Free of acid, dirt and water.
i. Low dielectric loss factor.
j. Strength of impulse and high resistivity.
k. Permitivity, high and low depending on usage.

The highest electric field strength can be known using the equation below, the equation below is used to determine the strength of an insulating material when carrying a high load (dieletric strengh):

$$E = \frac{V_{BD}}{d}$$

E = dielectric strength (kV/mm)
$V_{BD}$ = dielectric/insulating material (kV)
d = insulation thickness (mm)

### *II.3. Oil Isolation Limits*

The activity of testing the characteristics of transformer oil aims to determine the feasibility / testing of the requirements for transformer oil as cooling and insulation media. The following in Table 1 limits the used insulation oil according to the standards of IEC 60422: 1989, namely:

TABLE 1
LIMITATION OF USED INSULATION OIL

| No. | Limitation | Paratemters | |
|---|---|---|---|
| 1. | Colour | Good | Pale Yellow |
| | | Fair | Yellow Sawo |
| | | Not Good | Blackish Brown |
| 2. | Water Content | <20 mg/kg to >170 kV | |
| | | <30 mg/kg to <170 kV | |
| 3. | Breakdown Voltage | • 50 kV until >170 kV<br>• 40 kV until 70-170 kV<br>• 30 kV until <70 kV | |

## III. Research Methodology

Broadly speaking, this research was conducted with literature studies, experiments and analysis. The analysis uses descriptive statistical analysis method, namely by comparing data taken with an experiment with commonly used standards, then analyzing it with the basic theory that has been collected. The experiments carried out in this study were in the form of testing.

In the research carried out there are several tests carried out on one type of transformer insulation oil, but the oil to be tested is a type of crude oil with the brand Nynas Nitro Libra which has been used a long time since the last maintenance. This test is carried out by testing several parameters, namely the type of color, water content, and breakdown voltage with each temperature, namely using the ambient temperature around PT. PLN and the temperature of the UGM Chemical Engineering Laboratory environment.

Determination of standards and testing of oil quality based on standards, such as color parameters using the standard ASTM D1500 "Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)", the water content uses the standard ASTM 95 "Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation ", and breakdown voltage according to IEC 60422 standard" Method for the determination of electric strength of insulation oils ".

Fig. 1. Oil isolation samples

### *III.1. Testing Method*

- Color Testing
  Refers to the ASTM D1500 standard to determine whether the transformer oil insulation is feasible or not and free of impurities or sludge
- Testing of moisture content
  Refers to the ASTM D 95 standard to determine the water content derived from the oxidation process.
- Testing of Translucent Voltage
  Refer to the IEC 60156 standard to determine the ability of the insulating oil to withstand stress stress.

### *III.2. Testing Method*

Equipment used to test used oil, namely:

- Color Testing: Seta Lovibond Color Comparator
- Moisture: Fibroman – C
- Breakdodown Voltage: 100AF OTS Megger

### *III.3. Sampling Technique*

In carrying out oil extraction with bottles, there are several important steps that must be considered so that the tested oil sample does not change its characteristics.

- Dispose of a few ml of oil at the end of the sampling frame.
- Rinse the sample oil bottle with oil from the transformer jack.
- Fill the bottle with used oil, and don't contaminate it with dirt.
- Protect used oil from sunlight.
- Immediately bring oil samples to the laboratory.

# IV. Research Result

### IV.1. Testing Colour

In this test, the transformer oil sample that has been taken will be obtained the color intensity test. From the results of the examinations that have been carried out, the following data are obtained as seen at Table 2.

Abbreviation and acronyms should be defined the first time they appear in the text, even after the have already been defined in the abstract. Do not use abbreviations in the title unless they are unavoidable.

TABLE 2
TRANFORMER OIL COLOR TEST RESULTS

| Checking Type | Test Results | Examination Method |
|---|---|---|
| **Colour ASTM** | Crude Oil D 8.0 | ASTM D 1500 |

Based on the results of color testing using the Seta Lovibond Color Comparator tool. Color testing can be said to be a simple test because when testing only compares 2 pieces of oil sample, that is new oil with used oil and only need to do 1x test. Unlike the breakdown voltage test which must be done several times testing. Color testing gets the results of D 8.0, based on the ASTM D 1500 standard the results of D 8.0 have jet black color, so to obtain the results or not whether or not this oil is present in the ASTM results. The color results are used as an indication. Then from the results of testing the color D 8.0 has entered the level 7 oil type (crude oil), which is where the condition of this oil has a sludge and carbon content. So that used oil can be allowed to be used again, the oil must have a test result of <1.5.

### IV.2. Testing Water Content

In this test, the transformer oil sample that have been taken will be seen how much water there is. From the results of the tests that have been done, the data is as follows:

TABLE 3
TEST RESULTS OF TRANSFORMER OIL WATER CONTENT

| Checking Type | Unit | Test Results | Examination Method |
|---|---|---|---|
| **Water Content** | %Vol | Trace (0.02) | ASTM D95 |

*Trace means unreadable in the trap.

With the results of the above tests which still use the Vol% standard, then to compare with the standard needs to be changed into the form of mg / kg. Then use the following formula:

$$Water, \% \left(\frac{V}{V}\right) = \frac{Volume\ of\ trapped\ water}{Volume\ of\ sample} \times 100\%$$

$$Water, \% \left(\frac{V}{V}\right) = \frac{0.02}{50} \times 100\% = 0.0004\%$$

Information:

$$If\ 1\% = 10.000\ ppm$$

$$X_{(ppm)} = 10.000 \times 0.0004\% = 4\ ppm$$

*4 ppm = 4 mg/kg

Based on the results of testing the water content in the type of crude oil obtained 0,0004% volume, and changed units to mg / kg which is equal to 4 mg / kg, this result is still normal, because it does not exceed the IEC 60422 standard limit (15-20 mg/kg) The cause of oil contaminated by water is due to decomposition or exposure to oxygen when testing causes oxygen and water to enter the oil.

### IV.3. Testing Breakdown Voltage

In this test, the transformer oil sample that has been taken will be seen how much the strength of the oil to the excess voltage. From the results of the tests that have been done, the data is obtained as follows:

TABLE 4
TEST RESULTS OF TRANSFORMER OIL BREAKDOWN VOLTAGE

| Degrees Thermal (°C) | Breakdown Voltage (kV) | | | | | |
|---|---|---|---|---|---|---|
| | 1st Test | 2nd Test | 3rd Test | 4th Test | 5th Test | 6th Test |
| **22 °C** | 09.4 | 09.1 | 09.2 | 09.6 | 09.5 | 12.0 |

From the test results obtained on the test as many as 6x, will be made into graphical form in Figure 2, as follows:

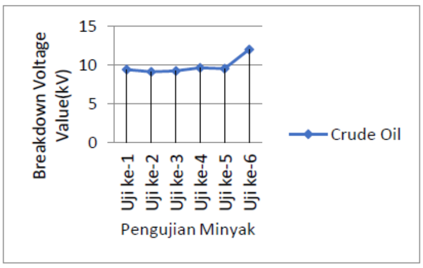


Fig. 2. Graph of oil breakdown voltage value

Based on Figure 4.1 curve, it can be seen that with the same temperature conditions there are differences in the value of the breakdown voltage in each Nynas Nitro Libra oil test with the condition of crude oil at 6 times the test. From the six curve images above, the first test curve until the sixth test experiences a fluctuating value of the breakdown voltage, on the sixth test curve the breakdown voltage value has a value of 12.0 kV. From the six tests we can see that, even though the ambient temperature has a fixed value of 22 ° C, the breakdown voltage test results remain variable. So, when the insulating oil is given an input voltage of 100.0 kV constantly, the condition of the oil will heat up and the higher the temperature of the oil, the higher the breakdown voltage. From the above test, it can be concluded while that the breakdown voltage value does not meet the minimum standard breakdown voltage for crude oil type, which is 50kV / mm2 for the category B transformer oil category, with a nominal voltage of 70 kV – 170 kV. This is in accordance with IEC 60422 standards. Method for determination of electric strength of insulation oils.

Isolation oil this type of crude oil is oil that has a lot of deposits because there are particles from the paper insulation that melt or the inner transformer environment is peeling because of the results of the oxidation process. Although this oil is already black, but if the breakdown voltage is still high, it can be said that it is still worth using for a while. Then in the first test the initial breakdown voltage was 09.4 kV, because the oil temperature still uses the temperature around PT. PLN that is equal to 22 ° C, but the value of this breakdown voltage has increased significantly until the 6th test which is equal to 12.0. this increase is due to the temperature of the oil when tested will continue to heat up, but in the second test and the fifth test, the turmoil breakdown value, this error occurs because there is a voltage resolution and the accuracy of the translucent voltage tester is 0.1 kV ± 1% ± 2% and also the error factor due to the temperature, humidity and condition of the ball-electrode testing.

From the results of the average breakdown stress above, the value of the dielectric strength can be calculated, as follows:

$$E = \frac{V_{BD}}{d}$$

- Calculation of the dielectric strength of the type of crude oil in the first test with a temperature of 22 °C.

$$E = \frac{V_{BD}}{d}$$
$$E = \frac{09.4}{2.5}$$
$$E = 3.76\ kV/mm$$

- Calculation of the dielectric strength of crude oil in the second test with a temperature of 22 °C.

$$E = \frac{V_{BD}}{d}$$
$$E = \frac{09.1}{2.5}$$
$$E = 3.64\ kV/mm$$

- Calculation of the dielectric strength of crude oil in the third test with a temperature of 22 °C.

$$E = \frac{V_{BD}}{d}$$
$$E = \frac{09.2}{2.5}$$
$$E = 3.68\ kV/mm$$

- Calculation of the dielectric strength of crude oil in the fourth test with a temperature of 22 °C.

$$E = \frac{V_{BD}}{d}$$
$$E = \frac{09.6}{2.5}$$
$$E = 3.84\ kV/mm$$

- Calculation of the dielectric strength of crude oil in the fifth test with a temperature of 22 °C.

$$E = \frac{V_{BD}}{d}$$
$$E = \frac{09.5}{2.5}$$
$$E = 3.8\ kV/mm$$

- Calculation of the dielectric strength of crude oil in the sixth test with a temperature of 22 ° C.

$$E = \frac{V_{BD}}{d}$$
$$E = \frac{12.0}{2.5}$$
$$E = 4.8\ kV/mm$$

With the results of the calculation of crude oil type samples with the 6x above tests, it will be used to find out the dieletric strenght value as a result that will be used for comparison with the IEC 60422 standard:

TABLE 5
AVERAGE OIL DIELECTRIC STRENGTH OF CRUDE OIL

| Degrees Thermal (° C) | Breakdown Voltage (kV/mm) | | | | | |
|---|---|---|---|---|---|---|
| | 1st Test | 2nd Test | 3rd Test | 4th test | 5th test | 6th Test |
| 22 °C | 3.76 | 3.64 | 3.68 | 3.84 | 3.8 | 4.8 |

From the results of calculations obtained in the test as many as 6x, will be made into graphical form in Figure 3, which is as follows:

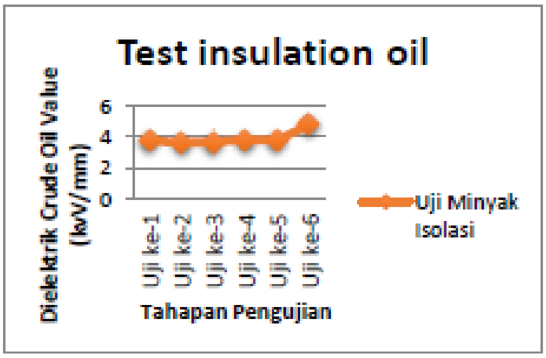


Fig. 3. Dielectric crude oil value curve with fixed temperature 22 °C

Based on Figure 3 curve above, the value of dieletric strength is obtained on Nynas Nitro Libra type oil which has a condition of crude oil. The isolation strength obtained is in the range of 3.76kV - 4.8kV / 2.5mm. This value indicates that the breaker voltage of the transformer oil type crude oil is below the minimum standard that has been applied which is equal to 30kV / 2.5mm based on SPLN No. 49/1982 (IEC 60422). The value of breakdown voltage will change if the oil temperature increases, then when this oil is used in the transformer and then experiences a load which causes the oil to heat up, the breakdown voltage of this used oil will increase. This is in accordance with the tests that have been carried out on 6x tests, that the breakdown voltage will change with the oil that is heating up because there is a constant voltage source of 100 kV which is added to the ambient temperature around the transformer.

## V. Conclusions

Based on the discussion of testing of used nitro libra oil on power transformers in the Bantul substation, it can be concluded as follows:

1. Based on the results of the Nynas Nitro Libra oil color test, there are differences in anticipation such as oil in new conditions, the new oil condition has a pale yellow color (D 0.5) which means there is no contamination from carbon or sludge. The oil being used is pale yellow (D 0.5), only slightly yellow because of the aging process. Whereas in the used oil sample with the condition of level 7 or Crude Oil (D 8.0), the condition of this oil already has a lot of carbon and sludge that has been mixed, from the result of the contamination the oil will turn black.
2. Testing the water content carried out on Crude Oil type oil samples only, obtained water content test data, namely Trace (unreadable) only slightly on the test trap between 0.02% Vol. Even though this oil has a former condition and the color type has been D 8.0 but the water content in the oil is very little. Because even though the color of the oil is dark, not necessarily the water content in the oil due to the decomposition of oil and paper is a lot.
3. From the results of the transformer oil breakdown test with reference to the IEC 60422 standard (standard 40-50 kV/2.5mm for the type of 150 kV transformer), the data shows that the new oil sample has an average breakdown voltage of 67.1 kV, in the event that the oil is categorized as feasible used, while oil is being used has an average breakdown voltage of 16.8 kV, in this case the oil is below the standard because it is less than 30kV for the function of breakdown voltage in oil, and used oil or Crude Oil has a flat breakdown value average of 09.8 kV, the oil has been said to be inadequate because it is far below the standard, with these conditions the positive oil is contaminated by impurities.
4. Translucent stress testing is carried out to determine the ability of insulating oil to withstand stress stress. Clear and dry oil will show a high breakdown voltage. Therefore the results of testing the type of oil color and breakdown voltage have a very close relationship to determine the quality of insulating oil. With the color test results, namely D 8.0 and the breakdown voltage values averaged 09.8 kV and the dielectric strength value was 3.92. Then the oil is positive for carbon deposits and sludge. And the function of oil as insulation is low, and the effect of contaminants is the cause of low breakdown voltage values.
5. The value of the water content can affect the value of breakdown voltage, the more water content, the smaller the value of breakdown voltage, there is little water content in the oil type of crude oil, but the breakdown value is small because the oil has been contaminated with impurities.

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