Reliability Evaluation of Transformer Oil Insulation with H2O Water and Super O2 Water Contaminants Disaster Mitigation Electrical Engineering

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Abstract: Transformer oil insulation failure is one of them that can cause water to penetrate through the mechanical acrylic cap on the OLTC (on load tap changer) which causes contaminants in the transformer insulation oil which affects the reliability of the transformer until there is damage to the transformers widely. For this reason, research was carried out to evaluate the reliability of transformer oil insulation with contaminants of H2O water and Super O2 water. This study is to evaluate the effect of water contaminants with experimental methods using BAUR Oil Tester test equipment, with H2O water and super O2 as samples of water contaminants on transformer oil insulation. According to SPLN 49-1: 1982, the standard value of breakdown voltage in insulating oil is ≥30kV/2.5mm. Then, 1ml of H2O water will be given so that a decrease in the breakdown voltage value of 31.5% is obtained and this experiment is carried out up to 10ml, which means that the more H2O is given, the value of the breakdown voltage is further away from the SPLN standard. Meanwhile, insulating oil contaminated with super O2 water obtained a breakdown voltage of 68% which means that the more super O2 water, the more the reliability of transformer oil insulation decreases, and the breakdown voltage value also decreases which adversely affects the reliability of the transformer.

Keywords: Water, insulating oil, breakdown voltage, transformer, contaminants

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Introduction

Transformer oil is a very important material for transformer equipment, which functions as a coolant and as a transformer insulation (Hidayat, 2020). Transformers have an important role because they function to transfer electrical power from the primary side to the secondary side through magnetic induction (Nurya Andayani, 2020; Suwoyo et al., 2022). Transformer oil consists of several types, namely mineral insulating oil, and vegetable oil, Mineral insulating oil is an oil that is often used in transformers and is obtained from the distillation process, while vegetable oil comes from the extraction of several plants that are used as mineral replacement oil (Jumardin et al., 2019; Sharma et al., 2020; Zhang et al., 2022). A good oil for transformers is oil that has a high breakdown voltage and dielectric strength, based on SPLN 49-1: 1982 (SPLN, 1982). The breakdown voltage is when the insulator is unable to resist the pressure of the electric field on the electrode that has a difference in potential so that the insulator can become a conductor. If the breakdown voltage value is small, the transformer insulating oil has a disturbance such as the presence of water contaminants (Maneerot & Pattanadech, 2018). When the temperature inside the transformer is high, it will cause vaporization of water. The electrolysis of water, which if the water located in a container is flowed through the electrode causes a chemical process (Christiono, 2022). The water contained in the transformer oil will not fuse, when the current flows in the coil, the water inside the oil will quickly lead to breakdown voltage (Winanta et al., 2019). Besides the effect of temperature that makes water appear, the appearance of water in insulating oil is also due to the water that enters through the acrylic OLTC mechanical cap. OLTC is electrical equipment that has a function to adjust the stable output voltage of a transformer whose input voltage magnitude is not always the same / different (Meliansyah, 2022). OLTC functions to regulate / keep the controlled output voltage stabilized. The high volume of water in the oil will make the transformer easily damaged and decrease the life of the transformer (Chumaidy, 2012; Gu et al., 2022; Irianto, 2015).

Table 1 Is a specification of insulating oil based on SPLN 49-1: 1982 (SPLN, 1982)

No.	Insulating Oil Characteristics	Unit	Class 1	Class 2
1	Purity	-	Clear	Clear
2	Density (20°C)	g/cm3	≤ 0,895	≤0,895
3	Kinematic Viscosity 20°C -15°C -30°C	cSt	 ≤ 40 ≤ 800 -	 ≤ 25 - ≤ 1.800
4	Flashpoint	°C	≥ 140	≥ 130

No.	Insulating Oil Characteristics	Unit	Class 1	Class 2
5	Pouring Point	°C	≤ -30	≤ -40
6	Neutrality	MgKOH/g	< 0,03	< 0,03
7	Sulphur Corrosion	-	Not corrosive	Not corrosive
8	Breakdown Voltage Before processing After processed	kV/2,5mm	 ≥ 30 ≥ 50	 ≥ 30 ≥ 50
9	Dielectric leaks	-	≤ 0,05	≤ 0,05
10	Oxidation resistance Neutrality Impurities	 mgKOH/g %	 ≤ 0,40 ≤ 0,10	 ≤ 0,40 ≤ 0,10

When the water in insulating oil is a high quantity, recommended actions are taken based on IEC 60422:2013 (IEC60422, 2013).

Table 2 Water in Insulating Oil

Oil Quality Requirements	Recommendation Limit	Recommendation Action
Water content (mg/kg at transformer operating temperature)	<15	Periodical maintenance Oil reconditioning Oil replacement combined with draining procedures.

From this explanation, a study was conducted by testing the breakdown voltage influenced by liquid contaminants using NYNAS mineral oil. Where the experimental results are the effect of water contaminants on the breakdown voltage based on SPLN, with the contaminant is 1ml to 10ml, using H2O water type, and super O2. Samples were tested using the BAUR Oil Tester DPA test equipment based on IEC 60156: 2018 (IEC60156, 2018) using half-ball electrodes with an intermediate distance of 2.5mm (Rouabeh et al., 2023).

Research Method

The research was done in the High Voltage Technology and Equipment Laboratory, with the title "Testing the Breakdown Voltage of Transformer Insulating Oil Affected by H2O Water and Super O2 Water Contaminants" using NYNAS insulating oil. The contaminants given are H2O water, and super O2 by 1ml to 10ml. the results of the research will be compared according to the SPLN 49-1: 1982 standard (SPLN, 1982). Testing the breakdown voltage value

using BAUR Oil Tester DPA with IEC 60156: 2018 standard (IEC60156, 2018). Then the calculation of the percentage reduction, and the calculation of the correlation.

Figure 1 Testing the breakdown voltage value of insulating oil using the IEC Standard BAUR Oil Tester DPA

The following is the flow of research conducted:

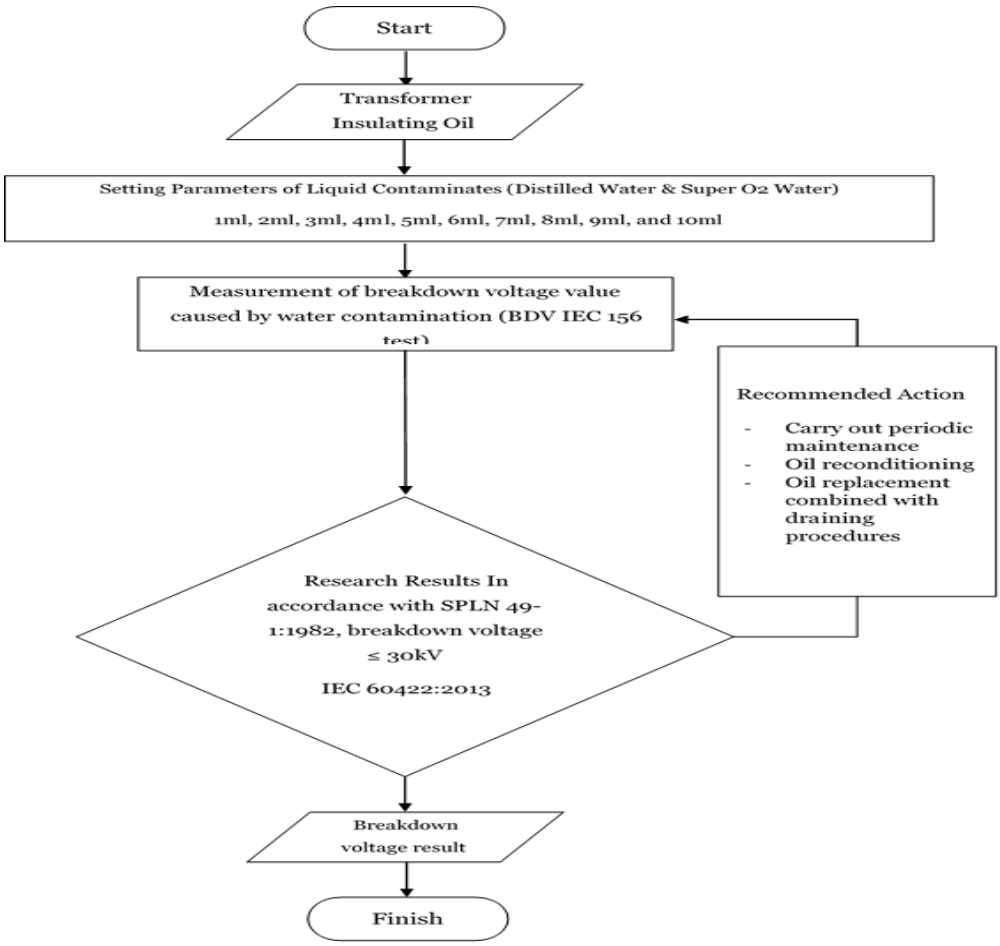

Figure 2 Flowchart Method Transformer Insulating Oil

Results and Discussion

The breakdown voltage happens in insulation oil when it is not able to withstand the field pressure on electrodes that have different potential values so that the transformer oil cannot be used to isolate. In this breakdown voltage test, the test was carried in 6 times, with an interval of 60 seconds for each test.

Table 3 Breakdown Voltage

No.	Type of contaminant	Quantity of Water Content	Breakdown Voltage Value Result (kV)
1.	Air H2O(distilled water)	1mL	33,4
		2mL	23,5
		3mL	21,2
		4mL	18,6
		5mL	18,7
		6mL	17,2
		7mL	17,1
		8mL	15,7
		9mL	15,2
		10mL	12,7
2.	Super O2 water	1mL	38,2
		2mL	34,8
		3mL	34,0
		4mL	32,2
		5mL	26,3
		6mL	24,3
		7mL	23,3
		8mL	23,0
		9mL	17,4
		10mL	15,8

From the average value of the breakdown voltage tested using distilled water contaminants and super O2 water given a 1mL to 10mL parameter, when the increasing water content in the insulating oil will affect the strength of the oil insulation. The transformer insulating oil contaminated by water will make the material of the transformer such as insulating paper will be broken which the paper can no longer protect the coil on the transformer. The insulation oil breakdown voltage value given distilled water contaminants is lower than the oil breakdown voltage value given super O2 contaminants. In super O2 water contaminants with 1mL to 4mL parameters, the transformer oil insulation withstands high voltage until the breakdown voltage is found to be measurable, where the insulating oil can perform self-healing or can repair the oil itself. The more contaminants, the oil is unable to withstand high voltages. The correlation calculation is carried out to know the correlation of the test parameters to the insulating oil used. Where the value of the coefficient of relation is between -1 to 1, the more positive the value found until it is close to 1, the relationship between the test parameters and insulating oil is going in the same direction. On the other hand, when the value

found is close to -1 to -1, the relationship between the parameters and the value of insulating oil will be reversed. The determination coefficient is used to know how big the percentage of the relationship between the parameters of the test and the insulation oil to be tested. The correlation calculation data, the results are as follows.

Table 4 Calculation of Correlation Effect of Sulphur Water Contaminants on the Breakdown Voltage in Insulating Oil

X1	Y1	(X1-Xrat) = X	(Y1-Yrat) = Y	X2	Y2	XY
1	33,4	-4,5	14,07	20,25	197,96	-63,32
2	23,5	-3,5	4,17	12,25	17,38	-14,6
3	21,2	-2,5	1,87	6,25	3,49	-4,68
4	18,6	-1,5	-0,73	2,25	0,53	1,1
5	18,7	-0,5	-0,63	0,25	0,39	0,32
6	17,2	0,5	-2,13	0,25	4,53	-1,07
7	17,1	1,5	-2,23	2,25	4,97	-3,35
8	15,7	2,5	-3,63	6,25	13,17	-9,08
9	15,2	3,5	-4,13	12,25	17,05	-14,46
10	12,7	4,5	-6,63	20,25	43,95	-29,84

Based on the Pearson Product Moment method, a correlation calculation is obtained for the test of the breakdown voltage affected by distilled water contaminants.

Table 5 Calculation of the correlation between the effect of super O2 water contaminants on the breakdown voltage of insulating oil.

X1	Y1	(X1-Xrat) = X	(Y1-Yrat) = Y	X2	Y2	XY
1	38,2	-4,5	11,27	20,25	127,01	-50,71
2	34,8	-3,5	7,87	12,25	61,93	-27,54
3	34	-2,5	7,07	6,25	49,98	-17,67
4	32,2	-1,5	5,27	2,25	27,77	-7,91
5	26,3	-0,5	-0,63	0,25	0,39	0,32
6	24,3	0,5	-2,63	0,25	6,91	-1,32
7	23,3	1,5	-3,63	2,25	13,17	-5,54
8	23	2,5	-3,93	6,25	15,44	-9,83
9	17,4	3,5	-9,53	12,25	90,82	-33,36
10	15,8	4,5	-11,13	20,25	123,87	-50,09

This calculation of the correlation value of the effect of super O2 water contaminants on the value of the breakdown voltage of transformer insulating oil.

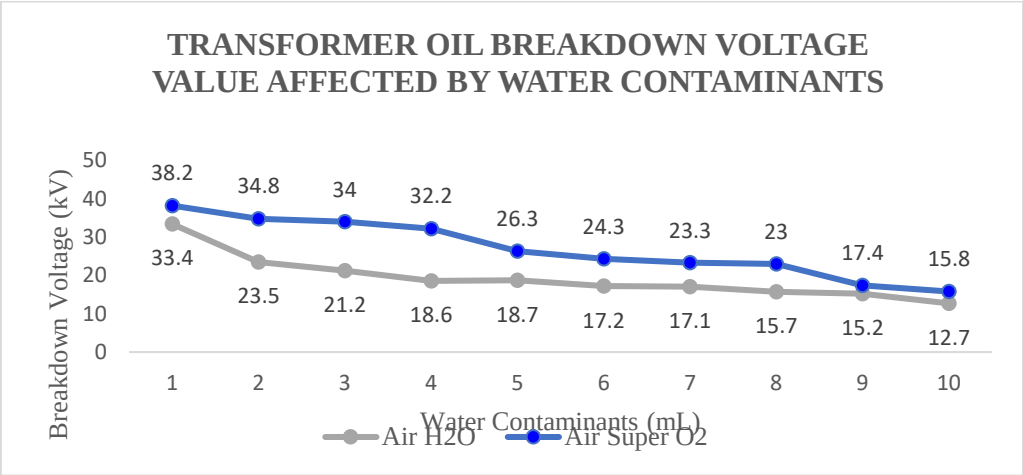

Figure 3 Comparison Graphic of the Effect of the Amount of Distilled Water Contaminants and Super O2 on the Value of Breakdown Voltage and Dielectric Strength.

Based on Figure 3, it can be seen the comparison between the breakdown voltage value affected by distilled water contaminants and super O2, at the breakdown voltage value given distilled water contaminants the highest value obtained is 33.4kV which value is still a safe limit in accordance with the standard value of SPLN 1982. Meanwhile, at the given 2ml to 10ml distilled water contaminants, the breakdown voltage value obtained decreases, as well as the breakdown voltage value resulting by testing using super O2 water contaminants, the more water content in the transformer insulating oil the faster the breakdown voltage happens, because the water contained in the oil will be easily affected by the flow of the electric field when the transformer is working. Where good transformer insulation oil should not contain water to make it easier for insulation failure to happen. When the insulation failure happens, the working transformer will be damaged quickly which will affect the paper insulation on the transformer.

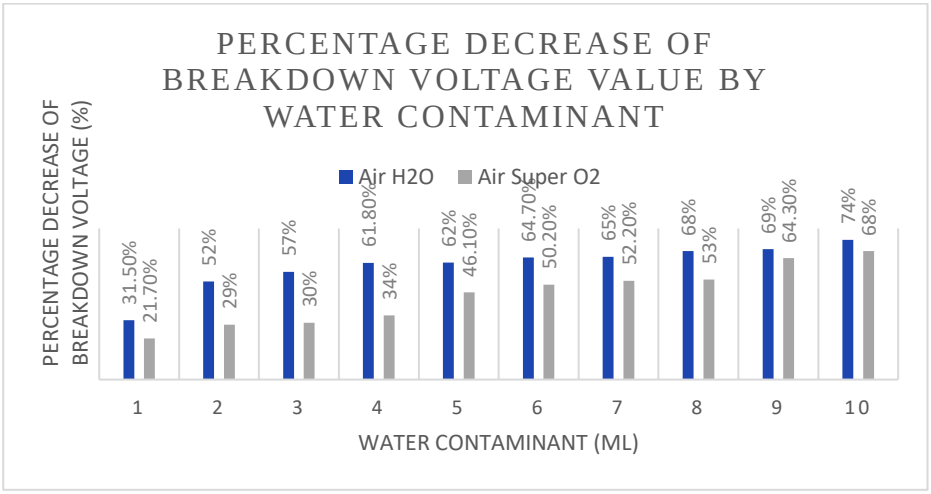

Figure 4 Comparison Chart of the Effect of the Quantities of Distilled Water Contaminants and Super O2 on the Breakdown Voltage Value and Dielectric Strength.

In Figure 4, it is known that the contaminant of H2O (distilled) water and super O2 water when the quantity is given 1mL, the decrease in the breakdown voltage value obtained is 31.5%, and 21.7%, where this value is a comparison with the breakdown voltage value in transformer insulating oil without contaminants as a benchmark. In the 2mL H2O (distilled) water contaminant given in the experiment, there was a 52% decrease in the breakdown voltage value, as well as in H2O water contaminants given as much as 3mL to 10mL contaminants. within the contaminants, the decrease in breakdown voltage found was 74%. Meanwhile, in super O2 water contaminants when given a lot of water 1mL to 10mL, the decrease in the breakdown voltage value is up to 68%, the more contaminants will affect the percentage decrease in the breakdown voltage value of insulating oil.

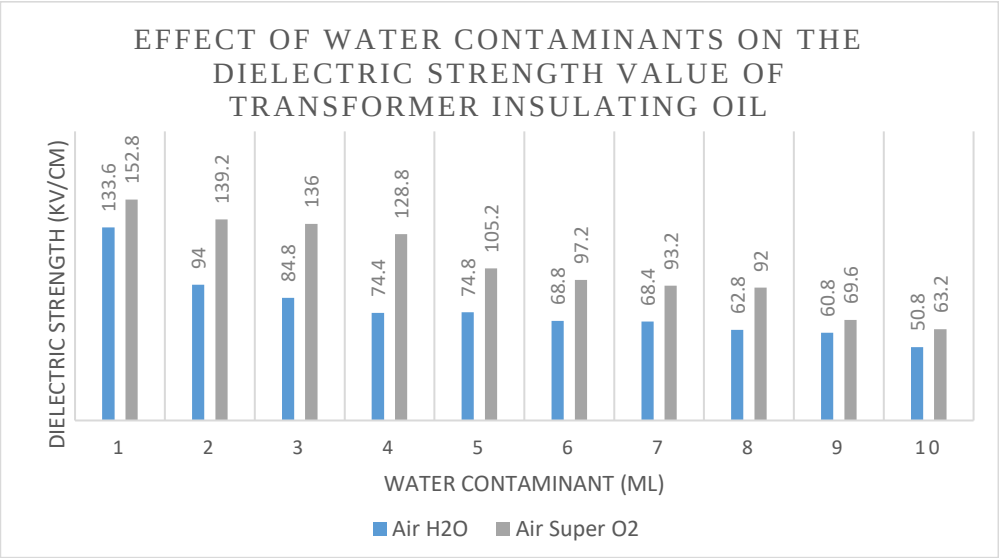

Figure 5 Comparison graph of the effect of the influence of water contaminants on the dielectric strength value of transformer insulating oil.

Based on Figure 5, the effect of contaminants on the breakdown voltage value and dielectric strength shows that the high and low breakdown voltage value will influence the dielectric strength value. When in the use of oil insulation there are water contaminants, it will decrease the transformer insulation work system. electrolysed water makes water easy to deliver the current, water molecules will be affected by the flow of the electric field which will form a spheroid that makes the breakdown voltage easy to happen, or makes the oil fail to carry out its function as an insulator.

Conclusion

In experiments using H2O water contaminants with the number of contaminants given 1mL to 10mL, it was found that the breakdown voltage value in the 1mL parameter still had a standard breakdown voltage value of 33.4kV. While the contaminant parameters as much as 2mL to 10mL the value of the resulting breakdown voltage is below the 1982 SPLN standard. Experiments with super O2 water contaminants showed that the breakdown voltage in the 1ml to 4ml parameters still had a standard breakdown voltage value, while the 5ml to 10ml parameters had a breakdown voltage value below 30kV. In the second experiment using different water parameters, it is known that the percentage decrease in the breakdown voltage value is up to 74%, which indicates that the more water is given, the greater the percentage decrease in the breakdown voltage value that will be produced. Of the two different contaminant breakdown voltage test results, it can be concluded that the result of the decrease in the breakdown voltage value is reversely proportional to the number of parameters given, and both have a breakdown voltage value that is below the breakdown voltage value of insulating oil without contaminants.

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