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Feasibility Test Based on Insulation, Ratio and Internal Protection for 20 MVA Power Transformer of 150/20 kV Substation

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ABSTRACT

The problems that occur in 20 MVA power transformers are insulation feasibility issues, voltage regulation and internal relay malfunctions. The impact is to cause a degradation of transformer reliability. The solution is how to ensure the feasibility of the transformer by evaluating the transformer feasibility test including the insulation subsystem, voltage ratio, and internal relay. This research discusses the feasibility of a 20 MVA transformer based on insulation, voltage ratio and internal relay. The model is a set of 20 MVA transformer GI 150 kV. The test method is carried out using polarization index, tangent delta, breakdown voltage, voltage ratio and sudden pressure relay function test. The references of all test methods are IEEE Std 62-1995 standard for polarization index, CIGRE TB 445 for tangent delta, IEC 60156-02-1995 for breakdown voltage, IEEE C57.125.1991 standard for voltage ratio and internal relay test validated using Proteus application. The test methods proved effective for evaluating the 20 MVA transformer feasibility test. This is evidenced by the worst value of 1.06 in testing the polarization index of the secondary to tertiary winding. Then 0.53% of tap voltage ratio 17 phase T and 0.58% of tap voltage ratio 18 phase T. The internal relay works as it should. The results obtained, the transformer is in an unfit condition and there needs to be further investigated so that it can be normally operated.

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1. INTRODUCTION

The 150 kV substation functions as an intermediary for the transmission of electricity from power centers to consumers ranging from industry, government offices to people's homes. The equipment at the substation is commonly called the Main Transmission Unit which has the function of protecting the reliability of electrical energy transmission. Some of the transmission equipment in a Substation are circuit breakers, disconnectors, current transformers, voltage transformers, capacitors, reactors, lightning arresters, and transformers. One important component in substation that must be ensured is the power transformer. The power transformer has a function to distribute power by transforming the voltage to a lower voltage or the reverse according to the designation of the type of distribution. The power transformer at the substation becomes the parent in the distribution of electricity to consumers. Therefore, the reliability of the power transformer must be maintained so that the continuity of electricity distribution is not disturbed [1]. The problem that occurs in 20 MVA power transformers is the problem of insulation feasibility [2]. This is caused by continuous use of the transformer, high loading exceeding 50% and interference caused by penetrating contacts [3]. In addition, on average, the transformer only goes out 1-2 days during the year for construction or maintenance. The infeasibility of transformer insulation can cause short circuits or faults that are dangerous for the safety of assets and also the safety of human life. In addition, the infeasibility of the voltage ratio causes poor voltage quality on the secondary side (20 kV). The infeasibility of the sudden pressure relay causes mall function in the transformer protection system. The solution is how to ensure the feasibility of the transformer so that it can operate according to standards, so an evaluation of the insulation subsystem, voltage ratio, and internal relays is needed.

Some previous research on transformer feasibility testing has been carried out, among others: 30 MVA transformer insulation resistance feasibility test using polarization index and tangent delta [1], comparison of the feasibility of power transformer insulation resistance using polarization index, tangent delta, breakdown voltage, and voltage ratio [2], using polarization index, tangent delta, and breakdown voltage [3], analysis of transformer oil breakdown voltage [4], analysis of insulation resistance in 150/30 kV power transformer [5]. The researchers successfully conducted transformer insulation tests with polarization index, delta tangent, and breakdown voltage. This research aims to determine the feasibility of 20 MVA power transformer. The methods used are polarization index, tangent delta, breakdown voltage, voltage ratio and internal protection. While previous studies focused on polarization index, tangent delta, breakdown voltage, and voltage ratio, this research expands on that by also including the sudden pressure relay function test because the terminal contact of the transformer's internal relay is very likely to leak, causing the malfunction of the trip circuit. The internal protection method is to determine the reliability of the internal relay modification circuit in the face of non-system faults by validating using Proteus software. As the object of research, the 20 MVA transformer of GI 150 kV Situbondo, East Java, Indonesia is determined.

2. RESEARCH METHODS

The feasibility of a power transformer can be determined by tests that represent each sub-system whose position is important from the transformer [6]. The insulation condition of the transformer is determined by testing the polarization index and tangent delta in the primary, secondary and tertiary windings, as with breakdown voltage testing to determine the condition of the transformer oil [2]. The feasibility of On Load Tap Changer (OLTC) is determined by testing the voltage ratio on each tap [2]. The condition of the internal relay circuit in the factory-set power transformer is very likely to cause malfunctions in the trip circuit of the transformer. Indonesian State Electricity Company which is the host of the 150 kV Situbondo Substation where the research was held, implemented a modification of the sudden pressure internal relay circuit to solve faults caused not from the system. Therefore, to determine the accuracy of the circuit, validation is needed between direct test results in this case a test trip, with simulations using the Proteus application [7].

2.1 Research Model

The research was conducted by testing the polarization index, tangent delta, breakdown voltage, voltage ratio and internal relay function test on a 150/20 kV power transformer with a capacity of 20 MVA. The 150/20 kV power transformer winding connection can be seen in Figure 1 [8].

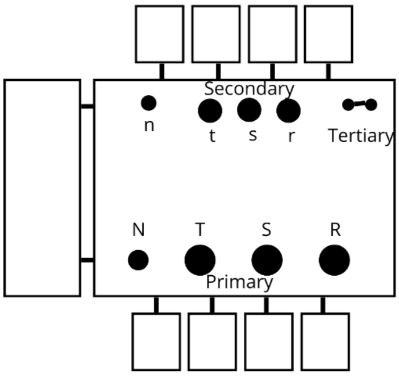

Figure 1. Winding of 150/20 kV transformer

The manufacturer specifications of the 20 MVA power transformer at 150/20 kV Situbondo Substation can be seen in Table 1.

Table 1. 150/20 kV Power transformer specifications

Specifications	
Merk	Xian
Type	SFZ-20000/150
Serial Number	A95022-1
Capacity	20 MVA
Voltage	150 / 20 kV
Year of Manufacture	1995

2.2 Testing Methods

Evaluation of the feasibility of a power transformer can be approached by conducting tests on each transformer subsystem. This research uses polarization index, tangent delta and breakdown voltage testing to determine the feasibility of insulation. As for the feasibility of the On Load Tap Changer (OLTC) voltage ratio, it is known by testing the voltage ratio. Then to determine the feasibility of internal protection is done by testing the function of the sudden pressure relay. The data obtained from the test results are validated using the formula of each test and then compared with the IEEE Std 62-1995 standard for polarization index, CIGRE TB 445 for tangent delta, IEC 60156-02-1995 for breakdown voltage, IEEE C57.125.1991 for voltage ratio and internal relay test validated using Proteus application to determine the level of transformer feasibility [9][10][11][12].

2.2.1 Polarization Index Test

Measurement of polarization index using insulation tester kit brand Kyoritsu. The test is carried out by providing dc inject voltage and then the resistance value is obtained in mega ohm units [13]. Polarization index testing is important to ensure that the equipment is suitable for operation or even for overvoltage tests. Continuous testing is carried out for 10 minutes, the insulation resistance will have the ability to charge high capacitance into the transformer insulation, and the resistance reading will increase faster if the insulation is clean and dry. The ratio of a 10-minute reading to a 1-minute reading is known as the Polarization Index (*PI*). If PI value is too low, this indicates that the insulation has been contaminated. The formula for testing the polarization index is given in Equation (1).

$$PI = \frac{Ris\ measurement\ 10\ min}{Ris\ measurement\ 1\ min} \tag{1}$$

2.2.2 Tangent Delta Test

Good insulation will be perfectly capacitive as well as an insulator that is between two electrodes on a capacitor [14]. Perfect capacitor properties, voltage and current phase shift 90° and the current passing through the insulation is capacitive. If there is a defect or contamination in the insulation, the resistance value of the insulation decreases and has an impact on the high resistive current passing through the insulation [15]. The insulation is no longer a perfect capacitor. The voltage and current will no longer shift 90° but will shift less than 90°. The magnitude of the difference in shift from 90° represents the level of contamination in the insulation. The delta tangent test is carried out to determine the dissipation factor or deviation factor of the transformer insulation against pure insulation which is capacitive in nature. The formula for delta tangent testing is shown in Equation (2).

$$Tan\ \delta\ = \frac{P}{V^2 \omega C} \tag{2}$$

where: δ : delta
P : power (watt)
V : voltage (volt)
C : capacitance (farad)
ω : $2\pi f$

2.2.3 Breakdown Voltage Test

Breakdown voltage testing is used to determine the ability of insulating oil to withstand voltage stress. Clear and dry oil will show high breakdown voltage values [16]. Free water and solid particles, let alone a combination of the two can reduce the breakdown voltage dramatically [17]. In other words, this test can be an indication of the presence of contaminants such as moisture and particulate matter [18]. A low value of breakdown voltage may indicate the presence of one of these contaminants and a high breakdown voltage may not necessarily indicate that the oil is free of all types of contaminants [19]. The formula for the delta tangent test is given in Equation (3).

$$E_{average} = \frac{V_{b\ average}}{d} \tag{3}$$

where: $E_{average}$: breakdown voltage (kV/mm)
V_b : test result (kV)
d : distance between electrode gaps (mm)

2.2.4 Voltage Ratio Test

The purpose of testing the winding ratio is basically to diagnose problems between windings and sections of the insulation system on the transformer [20]. This test will detect short circuits between windings, breakage of windings, or abnormalities in tap changers. The test method is to provide a variable voltage on the HV (high voltage) side and observe the voltage that appears on the LV (low voltage) side [21]. The ratio can be known by comparing the source voltage with the voltage that appears. Testing can be done using the transformer turn ratio test tool.

2.2.5 Function Test of Internal Relay Modification Circuit

The existing internal sudden pressure protection circuit has the potential to cause a fault due to broken contact [22]. If a broken contact occurs, the transformer immediately sends a trip signal to the power breaker to separate the transformer from the system. The sudden pressure internal protection circuit on the 20 MVA transformer has been modified so that if a breakthrough contact occurs, it will not extinguish the transformer, thereby increasing the reliability of electricity distribution. However, to ensure that this circuit functions properly, it is necessary to validate it by comparing the results of the function test directly on the transformer with the simulation of the circuit in Proteus software.

2.3 Research Flowchart

The research started with determining the research model according to Figure 1, then several test methods were carried out which produced polarization index data in Table 2, delta tangent in Table 4, breakdown voltage in Table 6, voltage ratio in Table 7 and internal relay function test in Table 9. Validation is carried out by comparing the test results with calculations referring to Equations (1) to (3), while for the voltage ratio the deviation is sought. All test results are compared with the IEEE Std 62-1995 standard for polarization index, CIGRE TB 445 for delta tangent, IEC 60156-02-1995 for breakdown voltage, IEEE C57.125.1991 for voltage ratio and sudden pressure internal relay function test validated using Proteus application. The research stages were carried out by referring to the flowchart according to Figure 2.

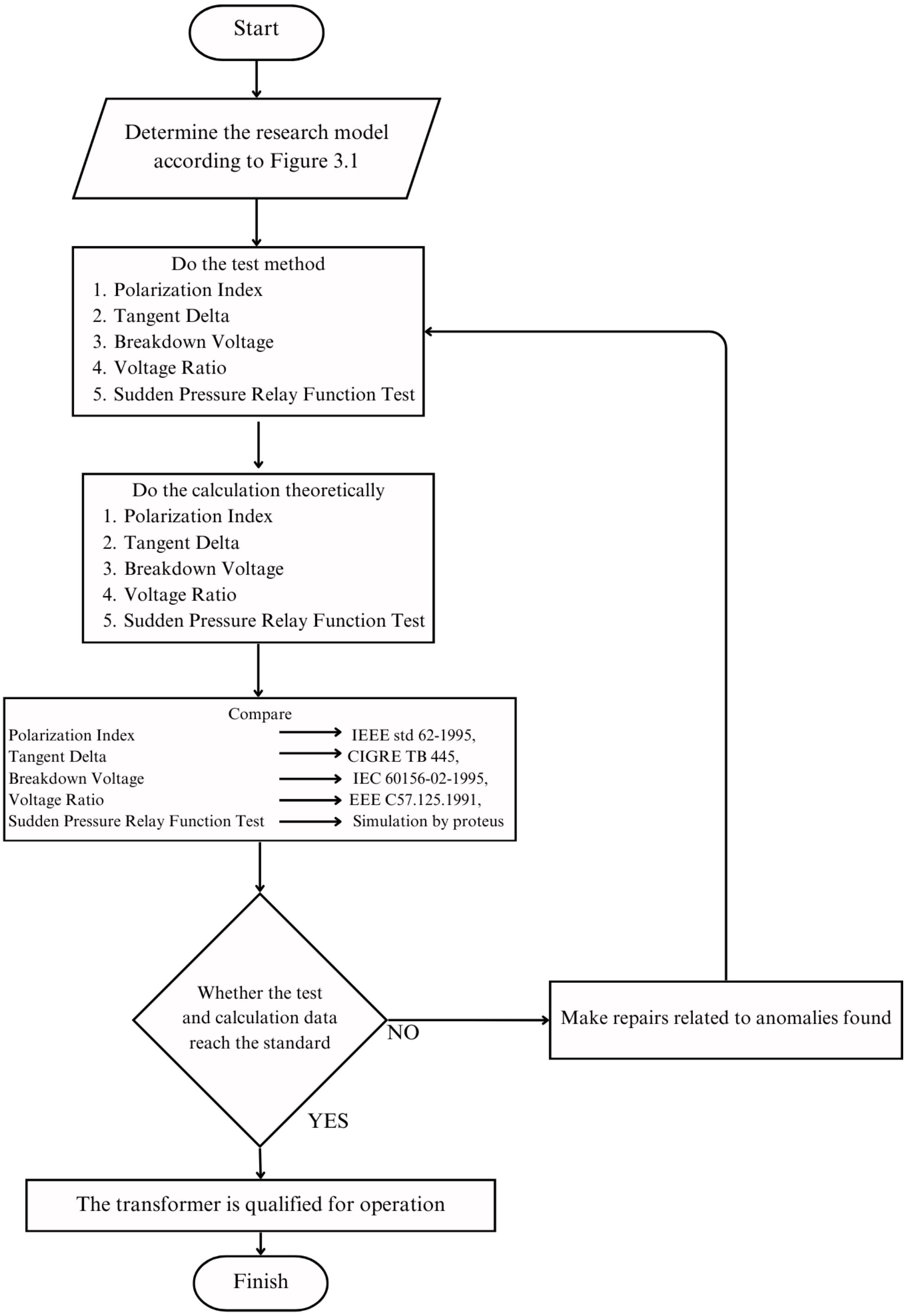

Figure 2. Research Flowchart

3. RESULTS AND ANALYSIS

3.1 Results of the Polarization Index Test

Polarization index testing is a test of the insulation resistance of the transformer winding at minute 1 and minute 10. This test aims to determine the feasibility of transformer insulation [23]. The stages of testing carried out include primary-secondary, secondary-tertiary, primary-tertiary, primary-ground, secondary-ground, and tertiary-ground [5]. The results of the polarization index test on the 20 MVA transformer can be seen in Table 2.

Table 2. Results of the polarization index test

Test	Polarization Index
Primary-Ground	1.19
Secondary-Ground	1.31
Tertiary-Ground	1.73
Primary-Secondary	1.34
Secondary-Tertiary	1.06
Primary-Tertiary	1.19

The results of the polarization index test are compared with the results of the calculation by referring to Equation (1), namely the value of the insulation resistance at minute 10 divided by the value of the insulation resistance at minute 1 [1]. The calculation example on the primary-ground winding is as follows.

$$\begin{aligned} PI &= \frac{1.25\ G\Omega}{1.05\ G\Omega} \\ &= 1.19 \end{aligned}$$

Based on the calculation of the example, the results of the polarization index calculation on the other windings can be shown in Table 3.

Table 3. Results of the polarization index calculation

Winding Connection	R minute 1	R minute 10	Polarization index
Primary-Ground	1.05	1.25	1.19
Secondary-Ground	1.13	1.49	1.31
Tertiary-Ground	0.984	1.71	1.73
Primary-Secondary	0.921	1.24	1.34
Secondary-Tertiary	0.588	0.625	1.06
Primary-Tertiary	1.26	1.5	1.19

3.2 Tangent Delta Test Results

Based on theory, good insulation is capacitive, but due to several factors such as age and contamination that cause insulation to decrease, this is indicated by the presence of resistive currents [24]. The delta tangent test aims to determine the condition of the insulation by comparing the resistive current with the capacitive current. This test is carried out on the primary winding, secondary winding and tertiary winding. Some of the modes used to conduct this test are UST (ungrounded specimen test) and GSTg (grounded specimen test with guard) [25]. The UST (ungrounded specimen test) method is used to test the delta tangent between windings without using a ground. While the (Grounded Specimen Test with Guard) method is used to test the tangent delta between the winding and the ground, the guard facility serves to eliminate references from other windings. Direct testing of tangent delta in routine 2-year maintenance on 20 MVA power transformers obtained test data as in Table 4.

Table 4. Result of tangent delta test

Winding Connection	Test Method	Tan Delta
Primary-Secondary	UST-R	0.39%
Secondary-Tertiary	UST-B	0.40%
Tertiary-Primary	UST-R	0.39%
Primary-Ground	GSTg-RB	0.58%
Secondary-Ground	GSTg-RB	0.87%
Tertiary-Ground	GSTg-RB	0.47%

Table 4 shows the tangent delta values found after the test. The test results are compared with the results of the tangent delta calculation using equation (2). An example of the calculation of the delta tangent in the primary to secondary winding (CHL) using Equation (2) is given below, so that:

$$\begin{aligned} \text{Tan } \delta &= \frac{0.5737}{10000^2 \times (2\times 3.14\times 50)\times(4768.85\times 10^{-12})} \\ &= 0.38\% \end{aligned}$$

The results of the calculation of the delta tangent in the winding connection according to Table 4 are shown in Table 5.

Table 5. Result of tangent delta calculation

Winding Connection	Tan Delta
Primary-Secondary	0.38 %
Secondary-Tertiary	0.40 %
Tertiary-Primary	0.39 %
Primary-Ground	0.58 %
Secondary-Ground	0.86 %
Tertiary-Ground	0.47 %

3.3 Breakdown Voltage Test Result

This test aims to determine the oil resistance to voltage where the role of oil in the transformer as an insulating medium [26]. Oil samples taken are in the transformer bottom maintank and also in the OLTC compartment through the draining valve facility. Then the sample is tested separately. Testing was carried out 6 times, where in the initial test for 5 minutes, the second test to the next 2 minutes each. The test equipment used is Baur DTA 100 C with a maximum voltage of 100 kV. The following is the breakdown voltage test result data. The breakdown voltage test results can be shown in Table 6.

Table 6. Result of breakdown voltage test

Testing Point	Test Results
Maintank	67.0 kV
Tank OLTC	51.8 kV

3.4 Ratio Voltage Test Result

Voltage ratio testing aims to determine the ratio value of each tap position. The ratio value shows the ratio between the primary winding and the secondary winding. The principle of voltage ratio testing is that the test equipment provides voltage input on the primary winding side, then another connection is connected to the secondary winding side to read the secondary voltage output. The ratio value is found from the calculation of the primary voltage divided by the secondary voltage [27]. The results of the voltage ratio test on the 20 MVA power transformer can be seen in Table 7.

Table 7. Result of Voltage Ratio Test

Tap Position	Phase	Test Results	Tap Position	Phase	Test Results
1	R	8.276	10	R	7.285
	S	8.276		S	7.285
	T	8.276		T	7.294
2	R	8.166	11	R	7.175
	S	8.166		S	7.175
	T	8.175		T	7.184
3	R	8.057	12	R	7.065
	S	8.057		S	7.065
	T	8.065		T	7.073
4	R	7.946	13	R	6.954
	S	7.946		S	6.954
	T	7.955		T	6.963
5	R	7.836	14	R	6.845
	S	7.836		S	6.845
	T	7.845		T	6.852
6	R	7.726	15	R	6.735
	S	7.726		S	6.735
	T	7.735		T	6.742
7	R	7.616	16	R	6.625
	S	7.616		S	6.624
	T	7.624		T	6.632
8	R	7.506	17	R	6.514
	S	7.506		S	6.513
	T	7.514		T	6.522
9	R	7.396	18	R	6.404
	S	7.396		S	6.404
	T	7.404		T	6.412

To determine the feasibility of the transformer ratio, the measured ratio value is compared with the calculated ratio, which is the primary voltage divided by the secondary voltage of each tap position listed on the transformer nameplate [1]. The results of the comparison obtained deviation then compared with the IEEE C57.125.1991 standard. The results of the calculation of the 20 MVA power transformer ratio can be shown in Table 8.

Table 8. Result of voltage ratio calculation

Tap Position	High Voltage	Low Voltage	Voltage Ratio
1	165750	20000	8.2875
2	163500	20000	8.1750
3	161250	20000	8.0625
4	159000	20000	7.9500
5	156750	20000	7.8375
6	154500	20000	7.7250
7	152250	20000	7.6125
8	150000	20000	7.5000
9	147750	20000	7.3875
10	145500	20000	7.2750
11	143250	20000	7.1625
12	141000	20000	7.0500
13	138750	20000	6.9375
14	136500	20000	6.8250
15	134250	20000	6.7125
16	132000	20000	6.6000
17	129750	20000	6.4875
18	127500	20000	6.3750

3.5 Sudden Pressure Relay Function Test Results

The function test is conducted to ensure that the sudden pressure relay modification circuit works as it should. Several cases are taken on the sudden pressure relay, then the response of the protection circuit is observed. The results of testing the internal transformer circuit can be seen in Table 9.

Table 9. Sudden pressure relay function test results

Event	CB 150 kV Condition	CB 20 kV Condition	Annunciator	Healthy Lamp
Normal	Close	Close	-	On
Contact NO of the sudden pressure relay is short-circuited	Close	Close	Pressure Relief	On
Trip via sudden pressure relay	Trip	Trip	Sudden pressure Trip	Off

3.6 Analysis of Polarization Index Test Results

The real polarity index test results listed in Table 3 when compared with the calculation results in Table 4 show the same results. Then the results are compared with the polarization index standard IEEE Std 62 of 1995 [9]. The polarization index is said to be good if the value is more than 1.25. The polarization index value between the primary winding and ground is 1.19. When compared to the standard [9], the value is in the questionable category. It is recommended to make advanced tests, one of which is the tangent delta test to identify the quality of the primary winding insulation to ground. The polarization index value between the primary and secondary windings is 1.34 where this result can be categorized as good. Similarly, the polarization index value of the secondary winding to ground is 1.31 where this result is categorized as good. The polarization index value between the secondary and tertiary windings has a value of 1.09 which is in the poor category. Investigation is needed to determine the feasibility of insulation between the primary and secondary windings. The polarization index value of the tertiary winding to ground is 1.79, this result is in the good category so there is no need for further investigation. The polarization index result of the primary winding to tertiary is 1.19, this when compared to the standard [9], is in the questionable category. Therefore, further tests are needed, one of which is the tangent delta test.

3.7 Analysis of Tangent Delta Test Results

The test results and calculations listed in Table 4 and Table 5 show no significant difference. Then the results are compared with the CIGRE TB 445 standard [10]. For transformers that are already operating, the maximum value of the delta tangent is 1%. If the value of the transformer delta tangent exceeds the predetermined standard, it is necessary to test the oil and insulating paper to find out the part that has worsened. The test results of the delta tangent between the primary and secondary windings using the UST-R method obtained a value of 0.39%, this result is categorized as good when compared to the standard. Furthermore, the connection between the primary winding and the ground with the GSTg-RB test method obtained a tangent delta value of 0.58%. This means that the tangent delta value of the primary winding to ground is still in the good category [10]. The secondary to tertiary winding connection has a tangent delta value of 0.40% when tested using the UST-B method. This result is categorized as good according to applicable standards. The secondary to ground connection has a value of 0.87% when tested using the GSTg-RB method. This value is the highest of all delta tangent test results, but it is still in the good category so no follow-up is required. The test results of the tertiary winding delta tangent to ground using the GSTg-RB method have a value of 0.47%. When compared to the standard, it is still in the good category. Furthermore, the primary tertiary connection tested using the UST-R method has a value of 0.39%. This result is still in the good category so there is no need for further investigation.

3.8 Analysis of Breakdown Voltage Test Results

The results of the breakdown voltage test on the maintank and OLTC compartment listed in Table 6 are then compared to the standard referred to in this study, namely IEC 60156-02 in 1995 [11]. The breakdown voltage value can be said to be good if the average of all tests is more than 50 kV. If the breakdown voltage value is in the range of 40-50 kV, it can be categorized as medium. If the breakdown voltage value is below 40 kV then it can be categorized as bad. Oil samples taken from the transformer maintank obtained an average breakdown voltage value throughout the test of 67.0 kV. When compared with the applicable standards, it is categorized as good. The results of oil testing on OLTC tanks obtained an average breakdown voltage value in all tests of 51.8 kV. When compared with applicable standards, it is categorised in good condition. The breakdown voltage test results revealed that the oil used as insulation in the main tank and the OLTC tank is still in good condition and suitable for use. Furthermore, only routine oil sampling is needed to monitor the condition of the transformer oil.

3.9 Analysis of Ratio Voltage Test Results

Based on the IEEE C57.125.1991 standard [12], the condition of the ratio between the primary and secondary windings is considered good if the test results have a deviation of less than 0.5% from the ratio established by the manufacturer. The ratio of each tap set by the manufacturer is usually indicated on the transformer's nameplate. If the deviation exceeds 0.5%, it is recommended to conduct further testing [28]. The deviation calculation results were obtained by comparing the name plate ratio in Table 8 with the test result ratio in Table 7. The deviation ratio values of the windings of tap positions 1 to 16 do not exceed 0.5% in each phase. Therefore, from tap 1 to tap 16, the ratio deviation is still in good condition. But at tap position 17, there is a deviation value of 0.53% in the T phase winding, and at tap position 18, there is a deviation value of 0.58% in the T phase winding. Based on the IEEE C57.125.1991 standard, if the deviation value exceeds 0.5%, further testing is required to determine feasibility. Following up on this, risk management is carried out based on time intervals. For the short term, other tests that are still part of the routine maintenance testing items are conducted to determine the winding feasibility with a ratio exceeding the standard, namely the delta tangent and breakdown voltage tests [6]. In addition, it is also necessary to monitor the substation staff when the transformer tap is in positions 16 and 17 to see if the voltage difference between phases is too far apart or not. For medium-term risks, an investigation of the transformer windings is necessary to determine their condition [29]. Meanwhile, for long-term handling, transformer replacement is necessary to ensure a more reliable electricity supply.

3.10 Analysis of Sudden Pressure Relay Function Test Results

The results of the transformer function test in real conditions when several cases were experimented with, followed by simulation using the Proteus application [7]. The first test case was conducted when the transformer was supplied with voltage. What happens in the real circuit on the control panel is that the healthy lamp lights up. The simulation in the Proteus application when the transformer is first powered can be seen in Figure 3.

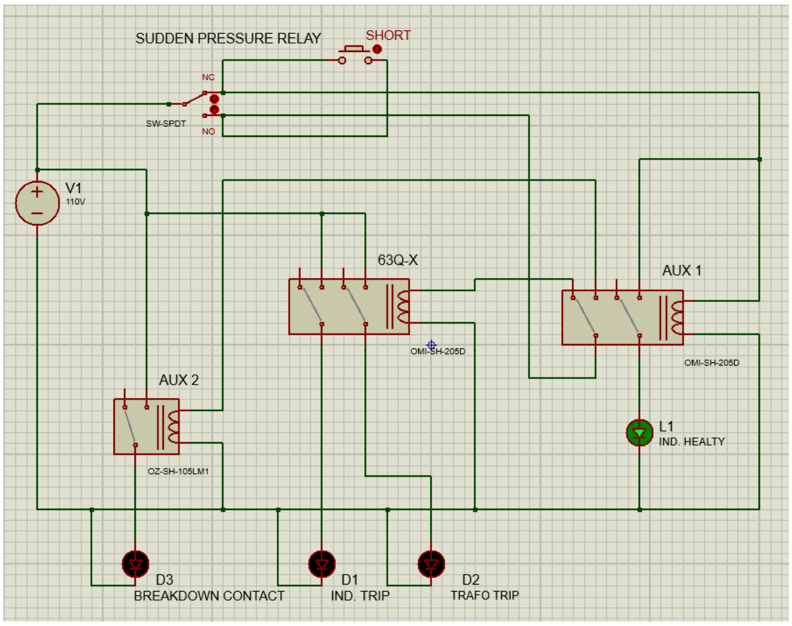

Figure 3. Sudden pressure relay circuit when the transformer is energized

When the simulation circuit is run, the healthy light turns on. Just like in the real situation where the internal relay modification circuit is installed, in the normal condition of the transformer, the healthy lamp lights up. This means that under normal conditions, the modified internal relay circuit operates as intended. Then, a second case is presented where the NO contact terminal is short-circuited as if a breakdown voltage occurs on the sudden pressure relay. The simulation when the NO contact of the sudden pressure relay is shorted can be seen in Figure 4.

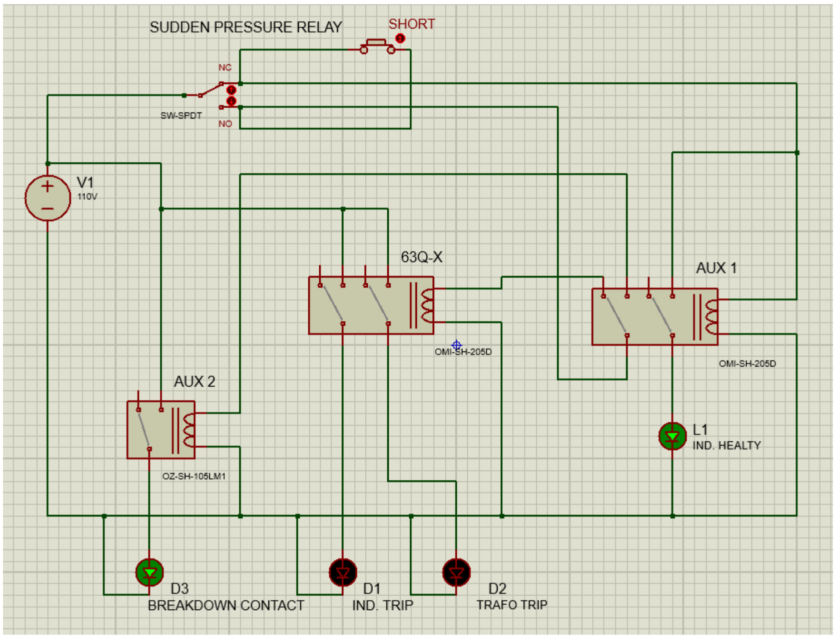

Figure 4. When the NO contact of sudden pressure relay is short circuited

Based on the actual test results when the NO relay sudden pressure contact was briefly connected in Table 9, the transformer did not trip. An annunciator appeared on the protection panel indicating that a dielectric breakdown occurred. Similarly to the real test, the simulation in Proteus shows the same result when the NO contact is short-circuited, which is the indicator light for the short circuit turning on, indicating a short circuit in the sudden pressure relay. Unlike the sudden pressure relay circuit before modification, which can be seen in Figure 5.

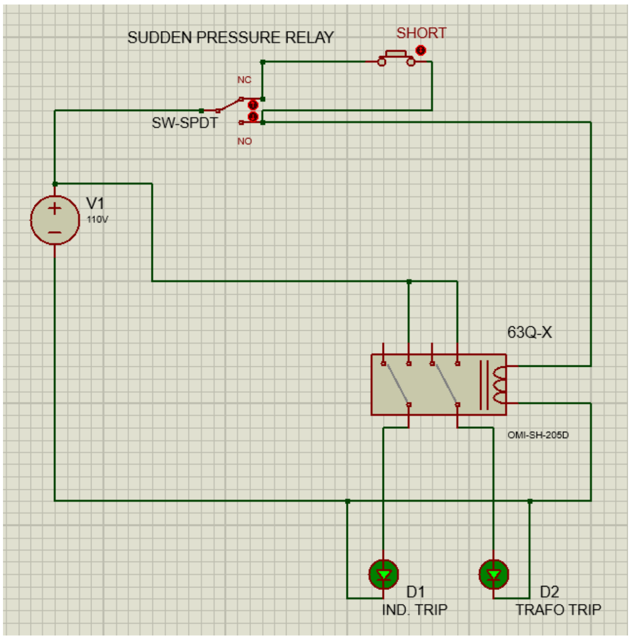

Figure 5. Sudden pressure circuit before modification

When the NO contact is short-circuited, the transformer immediately loses voltage or trips. This is because the positive dc voltage leads to the A1 contact of the contactor because the NO contact is connected. Then working on the 63Q-X contactor to send a trip signal to the circuit breaker and annunciator. This is the difference and at the same time the advantage of the internal relay modification circuit, which prevents the transformer from disturbances that are not from the system so as to increase the reliability of the transformer. If the sudden pressure relay is tripped as if there is a fault in the internal transformer, then something like Figure 6 occurs.

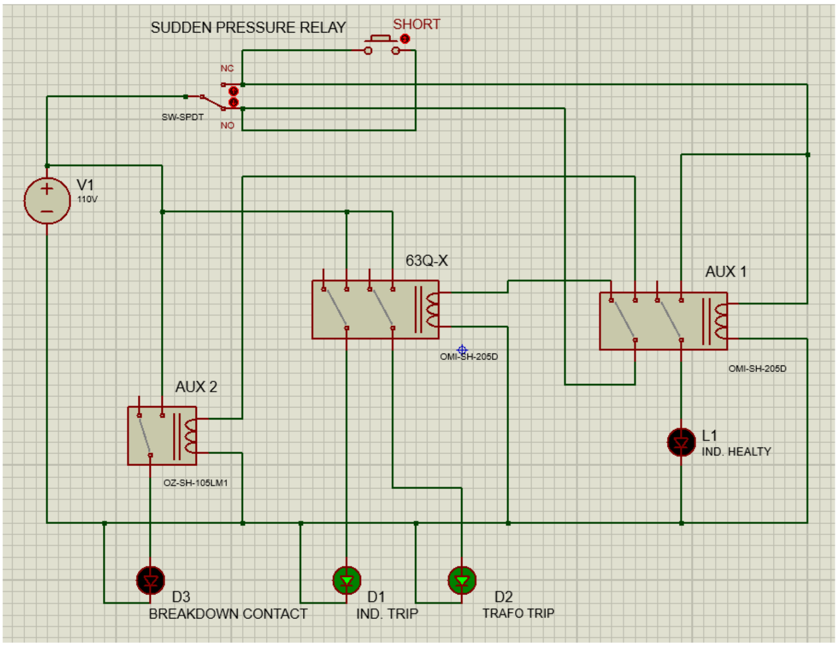

Figure 6. Modification circuit when the sudden pressure relay is tripped

When the sudden pressure relay is triggered, the circuit breaker on the transformer immediately trips. Similar to the real test, during the simulation the 63Q-X contactor transformer immediately sent a trip signal to the circuit breaker. In this case, the circuit works as it should. Judging from the wiring, this circuit also does not block the signal from the sudden pressure relay to trip the transformer so that the disturbance can be overcome by the circuit breaker of the transformer and does not extend to other circuits. Based on the function test of the sudden pressure relay modification circuit in real and simulated conditions, the three cases tried in the function test show the same response. This function test results revealed that this modified circuit supports the reliability of the transformer by preventing faults that come from outside the system.

4. CONCLUSION

The five methods can be used as methods to determine the feasibility of the 20 MVA GI Situbondo power transformer. Proven by the results of testing and calculating the same polarization index of all winding connections, the lowest value is 1.06 in the tertiary secondary winding connection, 1.19 in the connection between the primary-ground and primary-tertiary windings. When referring to the 1995 IEEE Std 62 standard, primary-secondary and primary-tertiary connections are recommended to conduct further testing, namely delta tangent and breakdown voltage, while for the secondary-tertiary winding it is recommended to Investigate. The results of testing and calculating the delta tangent of all winding connections obtained results that still meet the CIGRE TB 445 standard. The breakdown voltage test on the maintank and OLTC is still categorized as good based on the 1995 IEC 60156-02 standard. The results of testing and calculating the voltage ratio, there are 2 taps whose ratio does not meet the IEEE C57.125.1991 standard, which is phase T winding at tap positions 17 and 18. In the recommendation, other tests are carried out in this case, namely tangent delta and breakdown voltage. The modified series of internal relays is proven to prevent disturbances caused from outside the system such as penetrating contacts after validation with the Proteus application so as to increase the reliability of the transformer. Based on the analysis of all methods, the 20 MVA transformer at Situbondo Substation is in an unfeasible condition. Poor polarization index and voltage ratio results can threaten distribution reliability so that further investigation is needed on the insulation of the transformer windings that have decreased function so that the transformer is feasible to operate.

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