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Temperature Rise Test Of Distribution Transformers At Short Circuit Lab Certification Center

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Abstract: *One of the electrical equipment in the distribution system that has a very important role is the transformer. To maintain the reliability and performance of a transformer, it requires maintenance or even repairs that refer to the condition of the transformer. To find out the condition of the transformer, it is necessary to have electrical testing with reference to the SPLN and IEC standards. With this test, it is hoped that it will be able to detect early damage or irregularities that occur in the transformer and as a reference in taking further action. One form of this electrical test is the temperature rise test, with standards set for the Top Oil temperature of 50 K and 55 K for the average winding temperature. Based on the results of the temperature rise test on the 250 kVA distribution transformer, the results showed that the transformer being tested was in a condition suitable for operation.*

Keywords: Transformer, Electrical testing, Temperature, SPLN, IEC

1. Introduction

The rapid development of technology encourages the world of education to play a role in shaping the skills and skills of a person who is considered ready from a theoretical and practical perspective. To be able to support the knowledge that has been obtained while in the world of lectures, a student is needed to recognize the real picture and situation about the world of work.

Practical work is one of the compulsory courses at the Department of Electrical Engineering, Faculty of Engineering, Diponegoro University. The Electrical Engineering study program with a concentration in Electric Power Engineering will study various things related to electricity so as to support the learning process during lectures towards applicable learning in the field. Thus students can see directly and clearly the electrical system, so that students can directly observe the application of the theoretical knowledge obtained in the world of education.

Short Circuit Lab Certification Center is one of the platforms for students to explore their theoretical knowledge towards practical knowledge during field activities. Short Circuit Lab Certification Center is engaged in electricity certification and inspection.

Electrical energy has become a basic necessity for human life today. Electricity is needed for every level of society both for industrial activities, commercial activities, and daily life activities. Various equipment has been available to facilitate daily human activities, and in order to work properly, of course, the equipment requires an energy source. Primary energy available in nature cannot be used directly to operate the equipment, so energy conversion is needed first.

One of the components in electricity is the distribution transformer. Distribution transformers work by transforming electrical energy from high voltage to low voltage so that it can be used for industrial activities, commercial activities, and daily life activities of the community. Therefore, distribution transformers have a very important role in the distribution of electrical energy. Therefore, maintenance is one of the most important things that must be considered in the operation of the power system, because with a good maintenance system, the equipment in the power system can operate properly, thus creating high reliability. To find out the condition of the transformer before maintenance, it is necessary to do electrical testing. Through electrical testing, it can be seen how the condition of an electrical equipment, feasibility in operation, and reliability in operation.

2. Test Method

2.1 Temperature Rise Test Procedure

The test procedure for temperature rise in a three-phase distribution transformer is as follows:

1. Before testing the temperature rise, first calculate the power supply that will be given to the distribution transformer. Data for making calculations is obtained from routine test measurements. To calculate the power supply according to SPLN D3.002-1: 2020, namely using the formula:

   Load (power) = ∑ no load + ∑ load losses (tap 7)
   Tap 7, because the current value is the largest.
   Load (power) = ∑ No Load + ∑ Load Losses
   Load (power) = 292,83 Watt+ 2872,7 Watt = 3165,53 Watt

   The following is routine test measurement data used as a reference for injecting power into a 20 kV, 250 kVA 50 Hz distribution transformer:

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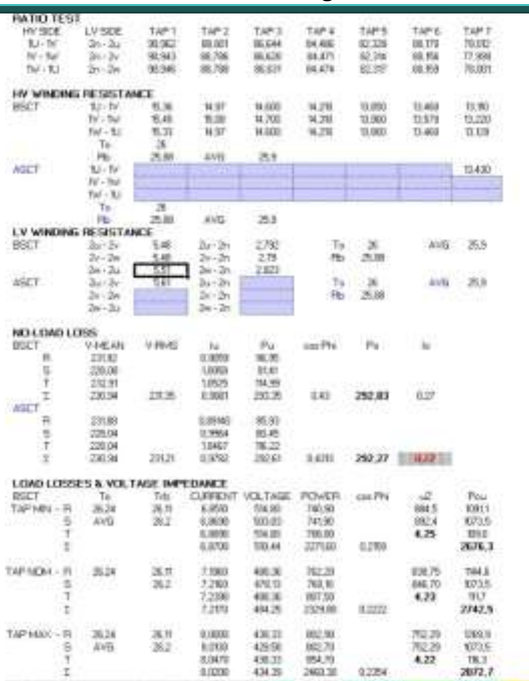


RATIO TEST

HV SIDE	LV SIDE	TAP 1	TAP 2	TAP 3	TAP 4	TAP 5	TAP 6	TAP 7
1U - 1V	2n - 2u	90.962	88.801	86.644	84.466	82.326	80.179	78.032
1V - 1W	2n - 2v	90.943	88.796	86.626	84.471	82.316	80.156	77.998
1W - 1U	2n - 2w	90.946	88.798	86.631	84.474	82.317	80.159	78.001

HV WINDING RESISTANCE

BSCT	1U - 1V	15.36	14.97	14.600	14.218	13.850	13.468	13.110
	1V - 1W	15.48	15.08	14.700	14.218	13.900	13.579	13.220
	1W - 1U	15.31	14.97	14.600	14.218	13.800	13.468	13.128
	Ta	26						
	Rb	25.88	AVG	25.9				
ASCT	1U - 1V							13.430
	1V - 1W							
	1W - 1U							
	Ta	28						
	Rb	25.88	AVG	25.3				

LV WINDING RESISTANCE

BSCT	2u - 2v	5.48	2u - 2n	2.792	Ta	26	AVG	25.5
	2v - 2w	5.48	2v - 2n	2.79	Rb	25.88		
	2w - 2u	5.51	2w - 2n	2.823				
ASCT	2u - 2v	5.61	2u - 2n		Ta	26	AVG	25.9
	2v - 2w		2v - 2n		Rb	25.88		
	2w - 2u		2w - 2n					

NO LOAD LOSS

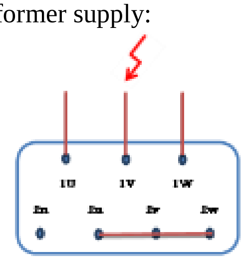
BSCT	V-MEAN	V-RMS	Iu	Pu	cos Phi	Po	Io
R	231.82		0.8059	96.35			
S	228.08		1.0069	81.41			
T	232.91		1.0525	114.59			
Σ	230.94	231.35	0.9881	293.35	0.43	292.83	0.27
ASCT							
R	231.88		0.8946	95.93			
S	229.04		0.9964	80.45			
T	228.04		1.0467	116.22			
Σ	230.94	231.21	0.9792	292.61	0.4311	292.27	[illegible]

LOAD LOSSES & VOLTAGE IMPEDANCE

BSCT		Ta	Tdc	CURRENT	VOLTAGE	POWER	cos Phi	uZ	Pcu
TAP MIN -	R	26.24	26.11	6.8500	514.90	740.50		884.5	1081.1
	S	AVG	26.2	6.8600	500.03	741.90		892.4	1073.5
	T			6.8800	514.80	786.80		4.25	1019.0
	Σ			6.8700	510.44	2271.00	0.2789		2676.3
TAP NOM -	R	26.24	26.11	7.1900	486.36	762.20		838.75	1144.8
	S		26.2	7.2100	470.13	768.10		846.70	1073.5
	T			7.2300	486.36	807.50		4.23	917
	Σ			7.2170	484.25	2329.00	0.2222		2742.5
TAP MAX -	R	26.24	26.11	8.0000	436.33	882.90		782.29	1069.9
	S	AVG	26.2	8.0100	429.58	882.70		782.29	1073.5
	T			8.0470	438.33	854.70		4.22	116.3
	Σ			8.0200	434.25	2460.30	0.2254		2072.7

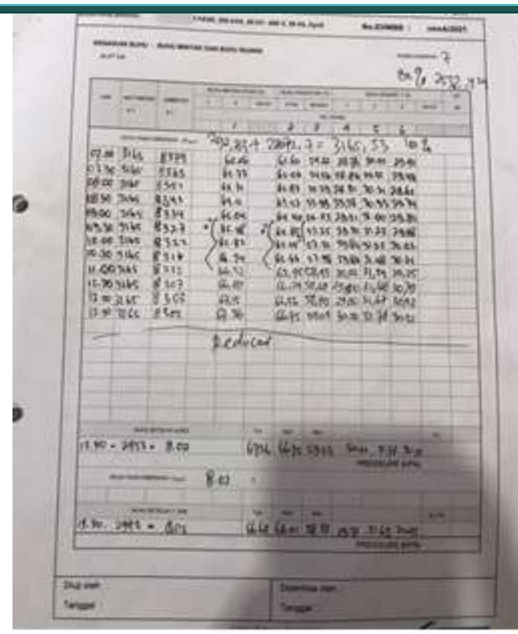
Gambar 2.1 Routine test data

2. Assembling the transformer for supply, here is the circuit for transformer supply:



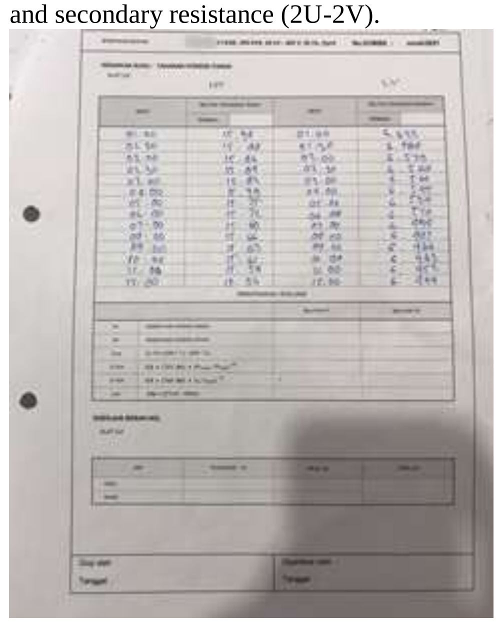
Gambar 2.2 Circuit for transformer supply

3. After the transformer is assembled correctly, the transformer is then fully loaded with a power supply of 3165.53 W until saturated.
4. Temperature data was recorded along with power and current at every 30 minutes using a thermocouple and powermeter, until it reached saturation point.



Gambar 2.3 Oil and chamber temperature rise data

5. Measure the pressure in the first minute the transformer is supplied with 100% power.
6. After the saturation point, reduce the current to the nominal current of tap 7, which is 8.02 A.
7. Reduce 3-phase transformer for 1 hour.
   After the transformer has been reduced for 1 hour, measure the primary resistance (1U-1V) tap 7 and secondary resistance (2U-2V). The following is the measurement data of primary resistance (1U-1V) tap 7 and secondary resistance (2U-2V).



Gambar 2.4 Primary and secondary winding resistance data

8. After getting all the data then do the overall calculation.

3. Temperature Rise Testing Results

3.1 Total Loss Injection

a. Test Load

Load loss, tap posisition 7	2873 W
No load loss	293 W
Total loss (Ptotal)	3166 W
Test Load (Ptest)	3166 W

b. Saturated Temperature

Top oil (θo1)	67,4 °C
Lower oil (θob1)	59,0 °C
Chamber (θa1)	30,8 °C.

c. Oil Temperature Rise and Tank Pressure at Rated Load

- Top Oil [K]
  $\Delta\theta o1 = (\theta o1 - \theta a1)\ x\ (PTOTAL / PTEST)^{0,8}$
  $\Delta\theta o1 = (67,4 - 30,8)\ x\ (3166/3166)^{0,8}$
  $\Delta\theta o1 = 36,5\ K$
  Standard requirements ≤ *50 K*
- Oil Average [K]
  $\Delta\theta o1r = 0,8 \times \Delta\theta o1$
  $\Delta\theta o1r = 0,8 \times 36,6$
  $\Delta\theta o1r = 29,2\ K$
- Tank Pressure
  25,55 kPA
  Standard requirements < *30 kPA*

Tabel 3.1 Oil temperature rise and tank pressure at rated load

No.	Test Objects	Test Results	Standard Requirements
1.	Top oil [K]	36,5	≤ 50
2.	Oil average [K]	29,2	-
3.	Tank pressure	25,55	< 30 kPA

3.2 Rated Current Injection

a. Test Current

Rated current (IN)	8,02 A
Test current (ITest)	8,02 A

b. Temperature after 1 hour

Top oil (θo2)	66,7 °C
Lower oil (θob2)	58,3 °C
Chamber (θa2)	30,6 °C

c. Oil Temperature Rise at Rated Current

- Top Oil (Δθo2)
  $\Delta\theta o2 = (\theta o2 - \theta a2) \times (I_N / I_{Test})^{1,6}$
  $\Delta\theta o2 = (66,7 - 30,6) \times (8,02/8,02)^{1,6}$
  $\Delta\theta o2 = 36,08\ K$
- Oil Average (Δθo2r)
  $\Delta\theta o2r = 0,8 \times \Delta\theta o2$
  $\Delta\theta o2r = 0,8 \times 36,08$
  $\Delta\theta o2r = 28,87\ K$

d. Winding Resistance

Cold Conditions (R1)	1U-1V	13,430 Ω
	θ1	25,90 °C
	2U-2V	5,612 mΩ
	θ1	25,90 °C
Hot Conditions (R2)	1U-1V	15,944 Ω
	2U-2V	6,622 mΩ

e. Average Winding Temperature Rise

- High Voltage Winding [K]
  $\Delta\theta w1 = (R2 / R1)\ (225 + \theta 1) - (225 + \theta a2) + (\Delta\theta o1r - \Delta\theta o2r)$
  $\Delta\theta w1 = (\frac{15,944}{13,430})\ (225 + 25,9) - (225 + 30,6) + (29,2 - 28,87)$
  $\Delta\theta w1 = 42,6\ K$
  Standard requirements ≤ 55 K
- Low Voltage Winding [K]
  $\Delta\theta w2 = (R2 / R1)\ (225 + \theta 1) - (225 + \theta a2) + (\Delta\theta o1r - \Delta\theta o2r)$
  $\Delta\theta w2 = (\frac{6,622}{5,612})\ (225 + 25,9) - (225 + 30,6) + (29,2 - 28,87)$
  $\Delta\theta w2 = 40,8\ K$
  Standard requirements ≤ 55 K

Tabel 3.2 Average winding temperature rise

No.	Winding	Test Result	Standard Requirements
1.	High Voltage Winding [K]	42,6	≤ 55
2.	Low Voltage WInding [K]	40,8	≤ 55

3.3 Zero Load Energized

After the calculation, the zero load is energized with a voltage of 242 Volts for 2 hours (105% of the rated voltage at zero load; 1,05 x 231 Volt = 242 Volt)

Test Results: Good, withstand 105% rated voltage at zero load for 2 hours, after temperature rise test.

3.4 Winding Temperature Rise Graph

a. High Voltage Winding Temperature Rise Test

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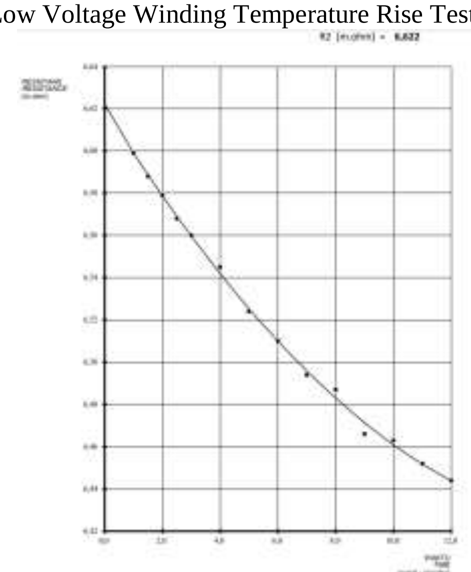
Gambar 3.1 Temperature rise graph of high voltage winding (primary)

b. Low Voltage Winding Temperature Rise Test



Gambar 3.2 Temperature rise graph of low voltage winding (secondary)

4. Conclusion

1. Short Circuit Lab Certification Center makes a huge contribution to PLN in particular and electricity consumers in particular by guaranteeing good quality electrical equipment after going through the testing stages according to applicable standards (SPLN, IEC), for the smooth and continuous distribution of electrical energy distribution.
2. In a three-phase distribution transformer, the measurement of the temperature rise value is carried out by attaching a thermocouple to 3 places, namely the thermometer / top oil bag, upper radiator, and lower radiator.
3. The test results of the distribution transformer temperature increase can be said to be good if the top oil temperature does not exceed 50 K and the primary and secondary winding temperatures do not exceed 55 K.
4. By observing the experimental results, the primary winding temperature value of 42.6 K and the secondary winding of 40.8 K both do not exceed 55 K, as well as the top oil temperature value of 36.5 K which also does not exceed 50 K, the tested transformer can be declared to meet the applicable standards, namely SPLN D3.002-1: 2020.
5. In the temperature rise test, the room temperature and the temperature in the radiator are very important to determine the final temperature in the distribution transformer.

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