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Testing of the 150 Kv Circuit Breaker Based on The Results of Isolation Resistance and Contact Resistance Tests

Enda Wista Sinuraya[1], Yuli Christyono[2] , Bambang Winardi[3], Agung Nugroho[4]

[1,2,3]Department of Electrical Engineering, Diponegoro University, Semarang, Indonesia
Email : bbwinar@gmail.com

Abstract: *Electricity is one of the most important energies for the sustainability of human life. In Indonesia, electricity is managed by the company PT PLN (Persero), which is the provider and supplier of electricity to all regions in Indonesia. One of the stages in the distribution of electricity is the transmission system at the main substation. Transmission at the main substation is a useful stage for lowering the voltage of electricity and as a means of connecting the generator system and distribution system before it is supplied to consumers. In the transmission system, regular maintenance of equipment at the main substation is necessary. One vital piece of equipment is the Circuit Breaker (CB), which functions to disconnect load currents both in normal and abnormal conditions to protect other equipment from damage. Therefore, the reliability of the CB must always be maintained. Examples of tests that are conducted to ensure the reliability of the CB include contact resistance testing and insulation resistance testing. Contact resistance and insulation resistance testing are usually conducted annually.*

Keywords: Electricity, Transmission, Circuit Breaker (CB), Maintenansi, Contact Resistance, Insulation resistance

1. INTRODUCTION

electric power system is divided into three main parts, namely generation, transmission, substation and distribution. Before electricity is distributed to consumers, electricity from the generating section is The transmitted first to the substation. The substation is part of the transmission system whose role is to regulate the flow of electric power and transform the voltage coming from the power plant to the desired voltage value. From this it is known that the transmission substation is a very important part in the distribution of electrical energy to consumers or the public at this time. The substation consists of various equipment that functions as a support for the transmission of electrical energy. Each of these equipment has different functions so that electrical energy can be transmitted properly. Therefore it is necessary to have routine maintenance so that the reliability and feasibility of the equipment at the substation is maintained.[1][2]

Maintenance or inspection of electrical equipment is a series of actions or process activities to maintain conditions and ensure that equipment can function as it should, so that disturbances that cause damage can be prevented. Maintenance carried out on equipment at the substation is classified into three, namely Level 1 Inspection (visual observation with the five senses while it is still voltage), Level 2 Inspection (maintenance by taking measurements while it is still voltage), and Level 3 Inspection (maintenance by measuring when not on voltage).

One of the equipment in the substation transmission system is a Circuit Breaker (CB). CB or often referred to as a voltage breaker (PMT) is a mechanical switch/switching equipment capable of closing, draining, (within a certain period of time) and breaking the load current under normal conditions as well as being able to close, drain (within a certain period) and cut off the load current within abnormal/fault conditions such as short circuit conditions. So that if the circuit breaker is damaged or disturbed, the operation of the transmission system will be disrupted and will damage other substation equipment. Therefore CB is one of the important equipment in the substation and its performance must be maintained.[3]

To keep the CB working properly, maintenance of CB level 3 or shutdown measurement is carried out. This level 3 inspection consists of testing insulation resistance, contact resistance, contact simultaneity testing, and grounding resistance testing. This maintenance is expected to maintain the reliability of the CB and to detect disturbances or damage if any. In addition, this maintenance aims to extend the use or life of the CB.[4][5][6]

2. TEST METHOD

2.1 Measurement of Insulation Resistance

Testing the insulation resistance of the CB is a measurement process using a measuring instrument to obtain the value of the insulation resistance of the circuit breaker in the part that is under voltage (phase) against the load (case) that is grounded or between the upper and lower terminals of the same phase. Basically the measurement of insulation resistance CB is to find out the magnitude (value) of the leakage current that occurs between the voltage-ridden upper and lower terminals to the ground.

Leakage current that penetrates the insulation of electrical equipment is unavoidable. Therefore, one way to ensure that the CB is safe enough to be given voltage is to measure its insulation resistance. Leakage current that meets the specified conditions will provide guarantees for the CB itself so as to prevent insulation failure. The formula for calculating the value of the leakage current is:[7][8]

$$I = V/R$$

Information :
I : Leakage current(A)
V : The voltage tested is usually 5000 V
R : Rated resistance (MΩ)

So it was found that the greater the value of the insulation resistance, the better. And if the insulation resistance value is low, there is fear that there will be insulation failure on the Circuit Breaker. The process of measuring insulation resistance is carried out according to the existing procedure, the first is the installation of local grounding, then cleaning the surface of the porcelain bushing, after that, the measurement of insulation resistance is carried out in open and closed conditions. Measurements were made using a megger meter (Insulation Tester) with a test voltage of 5 kV as shown in the figure below.

Figure 1. Megger Kyoritsu KEW 3125A

The tool used in this measurement or test is the Insulation Tester (megger). Insulation Tester is a tool commonly used to measure the value of resistance or resistance of the insulation that wraps the conducting material used in electric cables. Things that can cause damage to the measuring instrument are when the measuring instrument is used to measure objects in isolation where the surrounding electric induced voltage is very high to measure objects at locations where the electric induced voltage around them is very high or there is still a residual charge on the winding or cable. The step to neutralize the induced voltage and residual charge is to connect the part to the ground for a while so that the induction disappears.

To secure the measuring instrument against the influence of induced voltage, the equipment needs to be protected with a faraday cage and the connecting cables for the test circuit should use a cable equipped with a shield (Shield Wire). So to obtain valid results, the object being measured must be completely free from the influence of induction.

The procedure for measuring the insulation resistance test is:
1. Installation of local grounding (Local Grounding) on the side of the upper and lower terminals with the aim of removing any remaining residual voltage.
2. Cleaning the surface of porcelain bushings using paste + cloth with the aim that the measurements will obtain accurate values (results).
3. Measure CB insulation resistance in open conditions, including:
   1) Upper terminal (Ra, Sa, Ta) to cashing (body)/ground.
   2) Lower terminal (Rb, Sb, Tb) to cashing (body)/ground.
   3) Top - bottom phase terminals (Ra - Rb, Sa - Sb, Ta - Tb).
4. Measure CB insulation resistance in closed conditions, including:
   (1) R/red phase terminal (Ra + Rb) to ground
   (2) Phase S / yellow terminal (Sa + Sb) to ground T / Blue phase terminal (Ta+ Tb) to ground as shown in Figure 2.

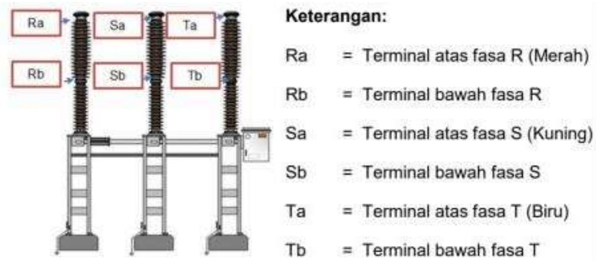

Figure 2. Terminal for CB Insulation Resistance Measurement

5. Figure 3. as an example when testing the insulation resistance of the CB between the upper and lower terminals.

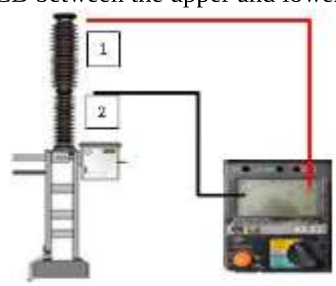

Figure 3. Top-bottom Terminal Insulation Resistance Test

Place the red wire on the top terminal and the black wire on the bottom terminal. Then turn the switch or test equipment scale to the 5000 Volt position, and set the time for 1 minute by pressing the "time set" button. The next step is to press the orange button and then turn right so that the results will appear after the time setting is met.

6. Record the results of measurements of insulation resistance and ambient temperature.
7. The results of this measurement are the latest measurement data and serve as evaluation material for comparison with the results of previous measurements. An example of a blank is attached ("Circuit Breaker insulation ground measurement result sheet").
8. Replace the top and bottom terminations as before. Removing local grounding while final inspection in preparation for further work.

2.2 Measurement of contact resistance

This test is carried out to determine the resistance value of the Circuit Breaker due to connection points that cause losses and to ensure that the fixed contact and moving contact in the CB are properly connected. CB position at the time of testing is in a closed state. The meeting of several conductors causes an obstacle to the current through it so that heat will occur and cause technical losses. This loss is very significant if the contact resistance value is high. The way to reduce the

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resistance value of the CB contact is to clean the contact with an iron rust cleaner and then brush it with the aim of cleaning dirt and rust that sticks to the contacts. For a description of the contact resistance test equipment with the Vanguard DMOM-200 brand, it can be seen in Figure 4.[9]

Figure 4. Measuring Instrument DLRO-600

The contact resistance measuring instrument consists of a current source and a voltage measuring instrument (voltage drop on the object being measured). With an electronic system, readings can be known properly and the accuracy is quite good (digital).

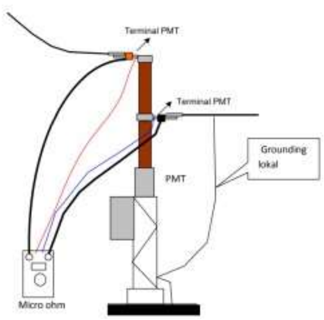

Figure 5. Contact Resistance Measurement Circuit in Switchyard

The procedure for measuring the insulation resistance test is:

a) Connecting the object to be measured to the ground.

b) Connect the (+) and (-) terminals to the terminals on both sides of the tool to be measured (object) as shown in Figure 8.

c) Connect the mVolt measuring cable as close as possible to the object to be measured.

d) Position the on/off switch to the on position. e) Selecting a switch on a 100-amperes scale.

f) Set the current generator so that the display shows 100 amperes.

g) Pressing the switch on the converter from amperes to ohms.

h) Record the indication and calibrate it against the limiting scale.

2.3. Specifications for Bay Transformer 1 Circuit Breaker (CB) at the 150 kV Srondol Substation.

Figure 6. Circuit Breaker Bay Transformer 1

Figure 7. Transformer Bay Circuit Breaker Name Plate 1

3. ANALYSIS OF TEST RESULTS

3.1 Insulation Resistance Test

The insulation resistance limit for CB is in accordance with the Equipment Maintenance Book SE.032/PST/1984 and according to the VDE standard (catalogue 228/4) the minimum amount of insulation resistance at operating temperature is calculated as "1 kilo volt = 1 Mega Ohm". Meanwhile, the minimum amount of leakage current at operating temperature is calculated as "1 kilo volt = 1 mA". Following are the results of the 150 kV CB insulation resistance test at transformer bay 1 GI Srondol with a test voltage of 5 kV can be seen in Table 1 below.

Table 1. Test Results/Measurements of Insulation Resistance

point	Standar	Measurement results (MΩ)		
		Fasa R	Fasa S	Fasa T
On - lower (MΩ) CB OFF	1KV/1	121	104	65.7
On - Ground (MΩ)		43.2	116	78.4

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CB OFF				
lower Ground (MΩ) CB OFF		62.1	32.8	52.3

After obtaining the insulation resistance value, the leakage current can be calculated by means of the voltage divided by the insulation resistance.

1. Calculation of leakage current at the up-down measuring point
   - Fasa R:

   Ib = 500V/121000 MΩ = 0,000041 mA

   - Fasa S:

   Ib = 500V/104000 MΩ = 0,000048 mA

   - Fasa T:

   Ib = 500V/65700 MΩ = 0,000076 mA

2. Calculation of leakage current at the above-ground (ground) measuring point
   - Fasa R:

   Ib = 5000 V/43200 MΩ = 0,000115 mA
   - Fasa S:

   Ib = 5000 V/116000 MΩ= 0,000043 mA
   - Fasa T:

   Ib = 5000 V/78400 MΩ = 0,000063 mA

3. Calculation of leakage current at ground measuring points
   - Fasa R:

   Ib = 5000 V/62100 MΩ = 0,000080 mA
   - Fasa S:

   Ib = 5000 V/32800 MΩ= 0,000152 mA
   - Fasa T:

   Ib = 5000 V/52300 MΩ = 0,000095 mA

The results of the CB insulation resistance test obtained in transformer 1 bay both on R, S and T phases, each phase to far ground is above 150 MΩ/kV and seen from the calculation results of good leakage currents on transformer 1 the average value is obtained far below the permissible leakage current value of 150 mA.

The normal standard value which is the reference is R < 120% of the manufacturer's value or the FAT test value, the value at the commissioning test. The following is a list of standard values for several CB manufacturers: Especially for CBs that do not have initial data, you can use the standard value of a similar type of CB or the lowest measurement value of the CB referring to the history of maintenance (trend 3 times the previous maintenance period).

And here are the results of testing/measurement of contact resistance on transformer bay 1:

Tabel 2. Hasil Pengujian/Pengukuran Tahanan Kontak

Point Measurin	Standar	Hasil Pengukuran (μΩ)		
		Fasa R	Fasa S	Fasa T
on – Lower CB ON	< 50μΩ	36,2	36	36,4

Based on table 2. above, it can be seen that the results of the 150 kV Circuit Breaker contact resistance obtained in transformer bay 1 both on R, S and T phases are all of a value below the CB maintenance manual standard, which is 50 μΩ, meaning that the CB contact device installed on transformer bay 1 Srondol Substation 150 kV PT PLN (Persero) ULTG Semarang is still in good condition and safe according to CB Maintenance Manual Standard R value < 50 μΩ / 120 % FAT value. If the value obtained exceeds the predetermined standard, which is above 50 μΩ , it is necessary to repair the clamps and clean the contact surface, then retest. If it is still above 50 μΩ, the tool will be replaced, because if it is forced to operate, it is feared that there will be damage to the Circuit Breaker due to the heat generated by the contact device.

After the contact resistance value is obtained and the value of the current flowing is 100 amperes known, the losses can be calculated using the formula:

$$P_{loss} = I^2 \text{ x } R$$

The following is the result of calculating the power loss due to contact resistance:

1. $Ploss\ Fasa\ R$ = 0,362 $Watt$
2. $Ploss\ Fasa\ S$ = 0,36 $Watt$
3. $Ploss\ Fasa\ T$ = 0,364 $Watt$

From these calculations it can be seen that the power losses caused by contact resistance have different values. From these calculations it can be seen that the power losses caused by contact resistance have different values. Losses caused by the connection points on the contacts are very small. This is because the contact resistance test results obtained have met the specified standards.

The magnitude of the power losses is influenced by two things, namely the value of the current used to test and the value of the contact resistance. In this connection, the greater the value of the contact resistance, the greater the resulting power loss. The smaller the value of the resulting contact resistance, the smaller the losses incurred. Likewise with the current, the greater the current that flows, the power loss will also be greater. If the contact resistance value is still below the standard allowable value of 50μΩ, then repairs to the Circuit Breaker (CB) contact do not need to be done.

Contact resistance testing is very necessary so that in each maintenance period the contact resistance value can be known, so that if the value is not in accordance with the allowable standard, repairs can be made to the CB contact. Repairs are carried out by resetting the CB drive and overhauling if necessary by thoroughly checking the CB contacts and then retesting. If the contact resistance value is still above the allowable standard, it is necessary to replace a new CB.

4. CONCLUSION

Circuit Breaker is a device used to open or close a circuit under load conditions and can open or close it in the event of a current interruption (short circuit) in the network. The difference between a three-pole and a single-pole CB is that a single-pole CB can trip one phase in the event of a one-phase to ground fault and can reclose one phase, while a three-pole cannot. And at the Srondol Substation, a three-pole CB is used for the transformer bay CB and the coupling bay, while the single pole type is used for the conductor bay. Insulation ground testing on a Circuit Breaker (CB) is a measurement process with a measuring instrument to obtain the value of the Circuit Breaker's insulation resistance on the part that is given voltage (phase) to the load (case) which is grounded as well as between the top terminal and the bottom terminal on the same phase. Minimum value of insulation resistance at a voltage of 150 kV according to the Maintenance Book standard Equipment SE.032/PST/1984 and VDE (catalogue 228/4) is 150 MΩ and R value > 1 kV/1 M. Test results for circuit breaker insulation resistance 150 kV at transformer bay 1 Srondol substation 150 kV PT PLN (Persero)) Semarang ULTG both in the R, S and T phases have met the standards of the Equipment Maintenance Book SE.032/PST/1984 and VDE (catalogue 228/4). The results of the 150 kV Circuit Breaker contact resistance test at transformer bay 1 Srondol Substation R, S and T phases have met the standards of the CB Maintenance Manual, R value < 50μΩ / 120% FAT value. The value obtained is below 5050μΩ

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