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# Feasibility Analysis of 150 Kv Circuit Breaker (PMT) for Padang Luar 2 Conductor Bay at Maninjau Substation

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The high-voltage electrical energy distribution system plays a crucial role in delivering electrical energy from generators to distribution or customers. This high-voltage distribution process starts from 30 kV to 150 kV. The transmission network connecting the Maninjau Substation and Padang Luar Substation uses bare conductors in its distribution. The use of bare conductors causes this transmission network to experience external disturbances. A reliable protection system is essential, so that if a disturbance occurs, it can be quickly detected and quickly isolated or removed from the disturbance current. The role of the protection system in providing signals or command input to the PMT greatly influences the PMT's performance. The PMT's role is also very vital, because the PMT must be able to operate when a disturbance occurs, whether under load or not. Therefore, PMT maintenance needs to be carried out periodically to prevent PMT failures. One of the causes of PMT failures is a low SF6 value, a high simultaneity value, a high contact resistance value, and others. High contact resistance in PMTs also significantly affects network losses. This research was conducted to examine how much the contact resistance value influences losses in the network and PMT performance, how much influence the PMT simultaneity has in isolating the presence of disturbances.
**Keywords:** PMT, Contact Resistance, Simultaneity, and Losses.



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## 1. Introduction

Based on IEV (International Electrotechnical Vocabulary) 441-14-20 it is stated that Circuit Breaker (CB) or Power Breaker (PMT) is a mechanical switch/switching device, which is able to close, flow and break the load current under normal conditions and is able to close, flow (in a certain period of time) and break the load current in abnormal/fault conditions such as short circuit conditions. While the definition of PMT based on IEEE C37.100:1992 (Standard definitions for power switchgear) is a mechanical switch/switching device, which is able to close, flow and break the load current under normal conditions according to its rating and is able to close, flow (in a certain period of time) and break the load current in specific abnormal/fault conditions according to its rating. Its main function is as a tool to open or close an electrical circuit under loaded conditions, and is able to open or close when a fault current (short circuit) occurs in the network or other equipment. When a short circuit occurs in the transmission network at the substation, the PMT will operate (open) to isolate the fault current so that it does not impact other operating bays. Therefore, the proper operation of the PMT is crucial to isolate the fault current so that it does not cause damage to other equipment. Damage to the Main Transmission Material (MTU) equipment at a substation can have fatal consequences for the distribution of electrical energy.

To extend the life of the equipment and ensure its proper functioning, circuit breakers (CBs) require routine maintenance or testing to determine their operational suitability according to standards. Therefore, this study aims to further study and analyze the feasibility of these circuit breakers.

This study was conducted to evaluate the routine maintenance of PMT, especially regarding the time synchronization of each PMT contact when working, PMT insulation resistance, and PMT contact resistance. The author examined the ALSTOM brand Circuit Breaker (PMT) located at the Maninjau Substation in Bay Padang Luar #2 150kV single pole which has been operating since 1982. This study provides an analysis of test results using a CB analyzer (Megger TM1800), contact resistance test results using DV power, and insulation resistance results using a megger. The focus of this study is to evaluate or analyze the results of PMT simultaneity tests using a CB Analyzer TM 1800, contact resistance using ddv power and insulation resistance using a megger.

## 2. Method

The research was conducted at the Maninjau Main Substation located in Tanjung Sani Village, Tanjung Raya District, Agam Regency, West Sumatra. This research was conducted during the 2-Year Maintenance (period) at Bay Padang Luar #2 at the Maninjau Substation. This maintenance was conducted using the Shutdown Measurement method (level 3). Maintenance items performed included testing the simultaneity of the ALSTOM Circuit Breakers (PMT). This maintenance was carried out in September 2024.

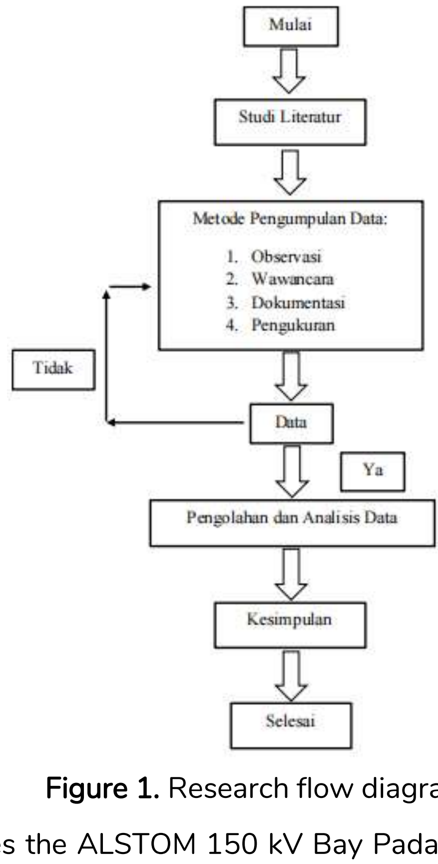


**Figure 1.** Research flow diagram

In this study, the author examines the ALSTOM 150 kV Bay Padang Luar 2 Circuit Breaker (PMT) at the Maninjau Substation.
The details are as follows:

| | |
|---|---|
| Brand | : ALSTOM |
| Rated voltage | : 170 kV |

| | |
|---|---|
| Rated lightning impulse withstand voltage | : 750 kV |
| Rated frequency | : 50 Hz |
| Standard no | : IEC62271-100 2001 |
| Year of manufacture | : 2013 |
| Rated short circuit breaking current | : 40 kA |

In order for the compilation not to deviate from the title or the problem that has been determined, the author limits the problem with the data used in the research only including data on the ALSTOM Circuit Breaker (PMT) Simultaneity testing work, contact resistance, and isolation resistance at the Maninjau Substation on September 19, 2024.

The methods used in writing this thesis are as follows:
Field Method

a. Field Observation
   This is a method of collecting data directly in the field using a camera, such as collecting PMT nameplate data, wiring diagrams and others.
b. Interview Method
   This is a data collection process through a question and answer session with employees at PT. PLN (Persero) ULTG Bukittinggi.
c. Literature Method
   This means collecting data by reading books in online/offline libraries that are related to the problem being faced.
d. Consultation Method
   This is a method used by the author by asking the supervisor directly, both the supervisor from PT. PLN (Persero) and the supervisor from Panca Budi Development University regarding the preparation of the thesis.

The data analysis techniques used by the author in this study are descriptive and quantitative. The data analysis techniques used in this study aim to provide an overview of the results of the insulation resistance, simultaneity, and contact resistance tests on the Circuit Breaker (PMT) which refer to the standards of the Director's Decree (520/Substation Maintenance Guidelines).

## 3. ResultsaAnd Analysis

### Contact Resistance Testing

Contact resistance testing is a test that functions to measure the electrical resistance value that appears at the point of contact between two conductor surfaces.

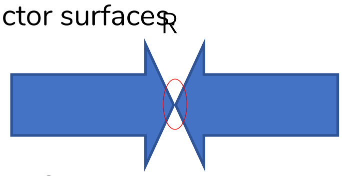


**Figure 2.** Contact Resistance Point

The electrical resistance that occurs at these connections results in power losses. Testing the contact resistance on a PMT ensures that the fixed and moving contacts are working properly. The greater the electrical resistance at the PMT's contacts or connections, the greater the power losses and the greater the likelihood of hotspots or even PMT failure.
This contact resistance test is performed with the PMT closed (the PMT is closing). The power loss at the PMT connection or PMT contact can be calculated using the formula:

$W = I^2 R$

Where :

W= Power loss (watts)

I = Current (Amperes)

R= Contact resistance (Ohm)

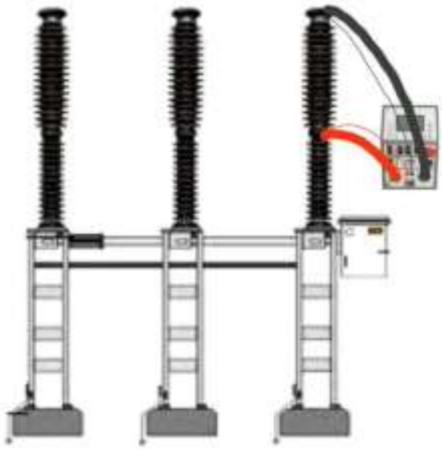

**Figure 3.** Contact Resistance Measurement Using DV Power

The contact resistance value limit of PMT is based on the IEC 60694 standard, R value ≤ 50 μΩ / 120% FAT value. Below are the results of the contact resistance measurement of PMT 150 kV Bay Line Maninjau - Padang Luar 2 (2024)

**Table 1.** Contact Resistance Measurement (of Conductors)

| 1 | PMT ON | Reference | R (μΩ) | S (μΩ | T (μΩ) |
|---|---|---|---|---|---|
| | 100 A injection | IEC 60694 R ≤ 50 μ ohm 120 % FAT value | 33.5 | 546.9 | 33.8 |

**Table 2.** Contact Resistance Measurement of (PMT Outer Plate)

| 1 | PMT ON | Reference | R (μΩ) | S (μΩ) | T (μΩ) |
|---|---|---|---|---|---|
| | 100 A injection | IEC 60694 R ≤ 50 μ ohm 120 % FAT value | 32.5 | 31.2 | 33.2 |

The contact resistance of the PMT was measured using a DV power meter. In this measurement, the PMT was injected with a current of 100 A. The contact resistance was measured by measuring the conductor and the outer plate of the PMT. After the measurements were taken, the two tables above were obtained. The two tables above show the following power losses.

**Table 3.** Calculation of Power Losses

| From the Conductor | From the Plate |
|---|---|
| **1. Phase R** | **1. Phase R** |
| $P=I^2R$ | $P=I^2R$ |
| $P=100A^2.33,5\mu\Omega$ | $P=100A^2.32,5\mu\Omega$ |
| $P=$0.335 Watts | $P=$0.325 Watts |
| **2. Phase S** | **2. Phase S** |
| $P=I^2R$ | $P=I^2R$ |
| $P=100A^2.546,9\mu\Omega$ | $P=100A^2.31,2\mu\Omega$ |
| $P=$5,469 Watt | $P=$0.312 Watts |
| **3. Phase T** | **3. Phase T** |
| $P=I^2R$ | $P=I^2R$ |
| $P=100A^2.33,8\mu\Omega$ | $P=100A^2.33,2\mu\Omega$ |
| $P=$0.338 Watts | $P=$0.332 Watts |

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Meanwhile, the electrical energy loss that occurs in the contact resistance measured on the PMT for 30 days (720 hours) is as follows:

$$W_{LOSS} = P_{LOSS} \times t$$

The electrical energy loss in the PMT is calculated from the PMT input conductor to the PMT output conductor.

1. Phase R
Wloss = 0.335 Watt x 720 hours
Wloss= 241.2 Wh
Wloss= 0.2412 kWh
2. Phase S
Wloss = 5,469 Watts x 720 hours
Wloss= 3,937.68 Wh
Wloss= 3.93768 kWh
3. Phase T
Wloss = 0.338 Watt x 720 hours
Wloss= 243.36 Wh
Wloss= 0.24336 kWh

If we assume that these power losses use the Basic Electricity Tariff (TDL) with an average cost per kWh of 1444 rupiah/kWH, then the power losses for 30 days are as follows:

Loss in 30 days = Wloss x TDL

From the contact resistance test of PMT 150 kV Bay Penhantar Padang Luar 2 in GI Maninjau, there is 1 phase that has a high contact resistance value or does not comply with the standard (IEC 60694 R value ≤ 50 μΩ / 120% FAT value). Therefore, it is necessary to re-measure to find which point or clamp has a high contact resistance value. From these measurements, the power loss value is very small except for phase S of 5.469 Watts. The smaller the contact resistance value, the smaller the power loss generated by the PMT.

The loose clamp on the PMT and the condition of the PMT clamp, which contains many pollutants, are the main factors that often occur when the contact resistance on the PMT clamp is high. After calculating the loss in rupiah, it tends to be small for 30 days, but this will cause a large loss impact if not addressed further. This high contact resistance can cause hot temperatures (hotspots) when loaded. The higher the load, the higher the hotspot (heat temperature generated). This hot temperature on the PMT can cause PMT malfunction or even breakdown.

Another effect is preventing overheating or hotspots in the PMT due to the high contact resistance value. The process of heating is not due to the high contact resistance value, but rather to the large current passing through the high contact resistance value, resulting in heat generation and consequent technical losses.

Case of contact resistance measurement results of conductors in phase S with a value of 546.9μΩ for 1 day (86400 seconds)

With :
P = 5,469 watt
E = P x t
E = 5.469 x 86400
E = 472.521 kilo Joules
Meanwhile, the heat energy produced from this contact resistance is

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1 joule ≈ 0.24 calories
Q = 472.521 kilo Joules x 0.24
Q = 113405 calories

This value is very large and does not meet the standards, if this value is not immediately corrected then the PMT will experience a hotspot which if operated for a long time will cause a breakdown.

**Insulation resistance testing**

**Figure 4.** Insulation Resistance Measurement Using DV Power

The purpose of this insulation resistance test is to determine the leakage current in a 150 kV PMT. This test is performed when the PMT is open. The insulation resistance test on a 150 kV PMT consists of three tests: top terminal - ground, bottom terminal - ground, and top terminal - bottom terminal.

The PMT insulation resistance standard according to the Equipment Maintenance Book SE.032/PST/1984 and according to the VDE standard (catalogue 228/4) the minimum insulation resistance at operating temperature is calculated as "1 kilo volt = 1 Mega Ohm". As for the permitted leakage current per kV = 1 mA. The following are the results of the insulation resistance measurements on the 150 kV PMT bay Padang Luar 1.

**Table 4.** Insulation Resistance Measurement Results

| MEASUREMENT | MEASUREMENT RESULTS | | |
|---|---|---|---|
| | PHASE R | PHASE S | PHASE T |
| Top - Ground | 69.8 GΩ | 19.6 GΩ | 19.2 GΩ |
| Ground | 217 GΩ | 172.4 GΩ | 241 GΩ |
| Up and down | 143 GΩ | 102.3 GΩ | 135 GΩ |

The results above are the results of injection using a Megger test tool with a DC voltage injection of 5000 V. The following are the results of calculating the amount of leakage current based on measuring the insulation resistance of a 150 kV PMT based on the following formula.

$$I = \frac{V}{R}$$

**Table 5**. Leakage Current Calculation Results

| MEASUREMENT | LEAKAGE CURRENT | | |
|---|---|---|---|
| | PHASE R | PHASE S | PHASE T |
| Top - Ground | 0.0716 mA | 0.255 mA | 0.26 mA |
| Ground | 0.023 mA | 0.029 mA | 0.02 mA |
| Up and down | 0.034 mA | 0.048 mA | 0.027 mA |

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From the results of the leakage current calculation above, it shows that each PMT phase has a different insulation value. This is because the conditions in the Maninjau substation area tend to be humid and often rain, which causes moss pollutants to appear on the outer surface of the 150 kV PMT, therefore causing the insulation resistance values obtained to vary. However, the results of this insulation resistance measurement are still in good condition (above 150 Mega ohms) in accordance with the VDE standard (catalogue 228/4) and the results of the leakage current calculation have met the permitted standard, namely 1kV = 1mA.

**Contact Simultaneity Testing**

The type of PMT used in Bay Padang Luar 2, Maninjau Substation, is single-pole, with each phase having its own drive. This type of PMT allows for autonomous operation in the event of a reclose fault (Single Pole Auto Reclose). The PMT simultaneity test is a 2-yearly test item, a type of shutdown measurement test. It is used to determine the operating time of individual PMTs and to determine the synchronism of PMTs when closing and opening. If the PMTs do not trip simultaneously during a permanent fault, the pole discrepancy relay issues a trip command to all three PMT phases.

This test aims to observe the time difference between the R, S, and T phases when opening and closing the contacts. This results in a simultaneity value in the form of delta time (Δt), or the highest and lowest time difference between the R, S, and T phases when opening and closing.

$$\Delta t = t_1 - t_2$$

Where:

Δt : time difference

t1 : highest time

t2 : lowest time

The reference value for opening time measurement from the manufacturer is ≤ 50 ms and closing is ≤ 100 ms based on reference values from several manufacturers.

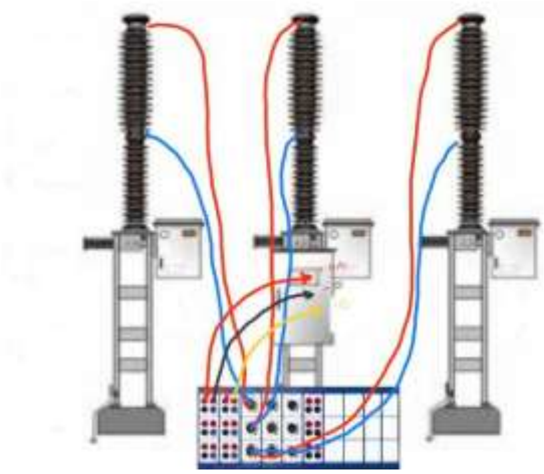

**Figure 5.** Simultaneity Measurement Using Megger TM1800

The time difference limit for simultaneity is Δt ≤ 10 ms (open/close) and 300 ms + 2 open + close times (for OCO time) based on the reference from the Alsthom manufacturer. After conducting the simultaneity test, the following results were obtained:

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**Figure 6.** Results of PMT Open simultaneity testing

**Table 6.** Results of the PMT Open Time Simultaneity Test

| Measurement of PMT contact simultaneity | | | | | |
|---|---|---|---|---|---|
| 1 | Opening hours | R (ms) | S (ms) | T (ms) | Delta t (ms) |
| | Testing | 24.7 | 24.6 | 24.3 | 0.4 |

**Figure 7.** Results of Close Simultaneity Test

**Table 7.** Results of PMT Simultaneity Test for Close Time

| Measurement of PMT contact simultaneity | | | | | |
|---|---|---|---|---|---|
| 1 | Opening hours (Close) | R (ms) | S (ms) | T (ms) | Delta t (ms) |
| | Test 1 | 96.1 | 99.9 | 154.6 | 58.5 |

The test results listed in the three tables above show that the delta time (Δt) or the highest and lowest time difference between the R, S, and T phases for the open time shows good results and the close time shows less good results. The test results show that the open time has met the standard time difference value limit, namely Δt ≤ 10 ms based on the reference from the Alsthom manufacturer and for the closing time or close has not met the standard time difference value limit, namely Δt ≤ 10 ms based on the reference from the Alsthom manufacturer. So that the PMT can trip according to normal simultaneity performance or its reliability can still be overcome. If the delta time value obtained is above 10 ms, the PMT's simultaneity performance is less reliable (can cause PMT malfunction) but when reclose (OC) occurs because the closing time is above the standard, namely 154.6 ms, this can gradually cause reclose failure because this is also one of the factors or signs of mechanical equipment that must be immediately

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maintained. The difference in time difference that is too long results in a surge in current or voltage in other phases which will cause damage to other equipment connected to the PMT, so repairs and retesting are needed on the PMT. However, if the value obtained still exceeds the standard, it is necessary to consider replacing it with a new PMT. If the results obtained during the first and second tests did not meet the established settings, we had to change the settings on the PMT panel. After changing the settings, the result for the third test was 1531.3 ms.

**Figure 8.** KT 6.1 Timer (Pole Discrapancy)

Case Maninjau-Padang Luar 2 Before the disturbance
V : 155 kV
I : 33 A

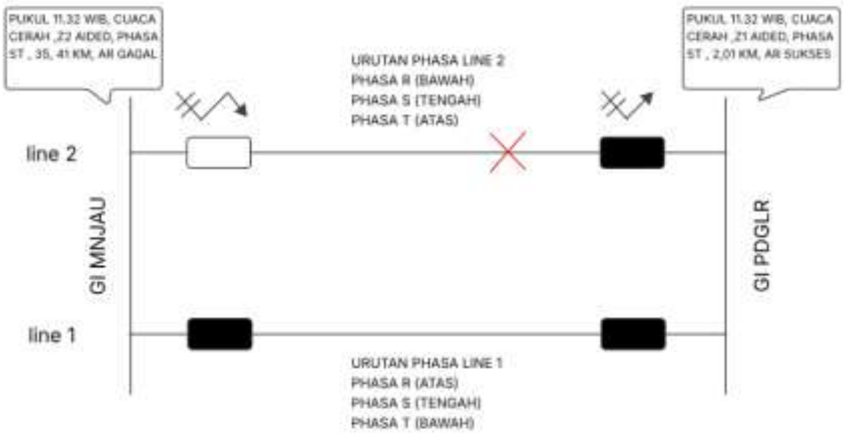


**Figure 9.** Chronology of Pht Disorders in Maninjau - Padang Luar 2

During the Maninjau-Padang Luar 1 disturbance at 11:32 WIB, the relay detected a temporary disturbance that required the relay to order a command to the PMT to reclose. After the reclose command was ordered to the PMT, the PMT carried out its task by releasing the PMT first, at the time of the incident the PMT successfully released/discharged the disturbance current by releasing the PMT. When the PMT wanted to close again, the PMT at the Padang Luar Substation successfully closed, but the PMT on the Maninjau Substation side had one phase left behind, causing Pole discrapancy to work. So the pole discrapancy ordered the PMT to release the 2 phases that had entered earlier (Failed to Reclose). This PMT failed to close because the PMT whose mechanical drive was jammed, reaching the time for the pole discrapancy to work. This pole discrapancy is very vital in its function considering that if the remaining phase is the phase that is disturbed, Zone 2 of the opposing GI will order a trip so that the GI in question will experience a Black Out (BO)

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## 4. Conclusion

Based on the results of testing, evaluation, and analysis of PMT Bay Padang Luar 2 at the Maninjau Main Substation, the following conclusions are drawn:

1. The results of the contact resistance test on the 150 kV PMT have not met the IEC 60694 standard of R value ≤ 50 μΩ / 120% FAT value. The value obtained from the injection test of the conductors exceeds the specified limit, which is 546.9 μΩ on the S phase.
2. From the results of the insulation resistance test on the 150 kV PMT, Padang Luar Bay 2, at the Maninjau Substation based on the VDE standard (catalogue 228/4), the value of R ≥ 1 kV/1 MΩ, the value obtained is above 150 MΩ, this shows that the 150 kV PMT has very safe insulation resistance.
3. According to the manufacturer's standard, the PMT difference between the PMT opening and closing delta T must be below 10 ms, so this 150 kV PMT does not meet the manufacturer's standard. The difference in the PMT opening time obtained from this simultaneity test is 58.5 ms, with the highest opening time being in the T phase, namely 154.6 ms.
4. The results of the pole discrapancy test of PMT 150 kV Bay Padang Luar 2 at the Maninjau Main Substation after 3 tests accompanied by timer adjustments obtained a result of 1531.3 ms, this is in accordance with the instructions of the main unit regarding pole discrapancy settings.

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