Effect of distance relay settings on interference zone reading on 70 kV transmission lines Bolok - Maulafa using Digsilnet 15.1.7

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Abstract. Distance relay is the main protection relay on the 70 kV Bolok - Maulafa transmission line. Distance Relay works by comparing the impedance on the line when in normal or abnormal conditions with the impedance attached to the relay. If the relay detects an abnormal condition in the line, namely when there is a short circuit or other disturbance, the relay will work according to the settings. The relay setting itself is divided into several areas of the relay work zone to work selectively in reading the disturbances that occur. This study aims to see how distance relay adjustment (Impedance Adjustment) affects the reading of the fault zone when there is a short circuit fault on the line. By using DigSILENT 15.1.7, the impedance is obtained according to the type of conductor used. By using the setup guidelines found on Doc: PDM / SGI15: 2014, the new tuning value for the distance relay on the 70 kV Bolok - Maulafa transmission line is obtained as follows: the new adjustment value for zone 1 and zone 2 carrying bay Bolok - Maulafa amounting to $4,698 < 70.18^\circ$ sec. Ohm and $13,658 < 70.18^\circ$ sec. Ohm. As for the delivery of Maulafa - Bolok, it was $4,264 < 70.18^\circ$ sec. Ohm and $6,076 < 70.18^\circ$ sec. Ohm. This new adjustment is compared with the adjustment of PT PLN in reading the fault zone by the characteristic curve of each relay using DigSilent 15.1.7. There is a 3-phase short circuit at the 10% point in the direction of Bolok to Maulafa relay with PT. PLN at Bolok Substation and Maulafa Main Substation reads disturbances in zone 1. While the relay with new settings at the Bolok substation reads disturbances in zone 1, and the relay at Maulafa Substation reads disturbances in zone 2.

1. Introduction
Regarding the reliability of electrical power distribution to consumers through the transmission line, protection equipment is needed that can and can quickly locate existing disturbances. The protection relay is one of the main components in the electric power system that can have a big impact on the reliability and stability of the electric power system [1]. On the 70 kV Bolok-Maulafa transmission line, the distance relay is used as the main protection relay, and the overcurrent relay and ground disturbance as backup protection. The distance relay works by measuring the transmission impedance divided into several coverage areas [1]. If the protection relay setting is not correct, the relay work system will not be selective, or a work error occurs.

The use of this protection equipment (Relay) which has been quite long and the occurrence of line disturbances can cause a decrease or error in relay work. Relay errors can endanger the protected line
which can lead to fatal consequences for the high voltage equipment used. Therefore, the settings given to the relay are expected to be able to read existing disturbances and be selective. The settings given greatly affect the reading of the disturbance zone that occurs, if there is a line disturbance. The reading of the fault zone can be seen from the characteristic curve of the distance relay. DigSILENT Power Factory (Digital Electronic Simulation and Network Calculation Program) is an engineering software that is useful for industrial analysis, electricity users, and electric power analysis [2]. A distance relay comparing the local line current with the current end at the far end of the line compares the local currency with the local voltage in the corresponding phase or a suitable component [3]. According to Tum et al. [4], one of the protection relays is distance relay, and it is mainly used in transmission lines. These relays sometimes are used for backup protection. Distance relays for determining the impedance need the voltage current. In addition, the types of faults are identified by proposed scheme of which is choosing neural network to especially distinguish internal disturbance and external disturbances. Then, Azzriyenni and Mustaf [5] describes how to design and develop new techniques to detect the type of error by using hybrid Intelligent Techniques. While Khoa et al. [6] focuses on analyzing and evaluation impact of a Static VAR Compensator (SVC) on the measured impedance at distance protection relay location on power transmission lines. When a fault occurs on the line is determinate by using voltage and current signals from voltage and current transformers at the relay and the type of fault occurred on the line.

2. Theoretical background

2.1. Electric power transmission

Electric power transmission is the process of distributing electricity from power generation centers to electricity distribution channels to be distributed to electricity users later. The transmission line is divided into three types of lines based on the length of the channel [7].

\[ Z = R + jX \] (1)

Where:
- \( Z \) = total series impedance per phase (Ω)
- \( X \) = total inductive reactance and capacitance of one conductor (Ω)
- \( R \) = total resistance of one conductor (Ω)

2.2. Protection relay

2.2.1. The release element. The parts of the protection relay consist of three main parts as follows [8]:

- Sense Element, this Element functions to sense electrical quantities, such as current, voltage, frequency, and so on, depending on the relay used. In this section, the state of the incoming quantity will be felt, and whether the protected state is disturbed or in a normal state, then the quantity is sent to the comparison element.

- Element of Comparison, this Element functions to receive the quantity after the sensing element first receive it to compare the electric quantity during normal conditions with the current magnitude of the relay.

- Defining Element, this Element serves to make changes quickly in the amount of size and immediately give a signal to open the PMT (CB) or give a signal.

![Figure 1. General parts of the protection system [9].](image-url)
2.2.2. **Protection relay requirements.** Relay protection is designed to sense or measure a disturbance or start sensing abnormalities in the equipment or parts of the electric power system. Therefore, the protection relay must meet the following conditions [10].

- Reliable, the relay may not work in normal circumstances, or there is no interference. However, if one day there is a problem requiring the relay to work, the relay must not fail to overcome the disturbance. In addition, the relay must not work wrongly, causing unnecessary blackouts or making it difficult to analyze the disturbances that occur. The safety relay is expected to have a long usage period.
- Selective (Selective) relay is in charge of securing equipment or part of the system in its security area. In other words, security is declared selective if the relay and PMT that work is only in disturbed areas.
- Fast Relay Working Time, the safety relay must work quickly as soon as it senses a disturbance in the system to reduce further damage to the equipment or affected part of the system.
- Sensitive, the relay must work with high sensitivity, meaning that it must be sensitive enough to disturbances in the area even though the disturbance is minimal.
- Economical and Simple (Cheap and Simple), One thing that must be considered as a safety relay requirement is the issue of price or cost. A relay will not be applied to the electric power system if the price is very high. Requirements for reliability, sensitivity, selectivity, and working speed of the relay should not cause the relay price to be high.

2.3. **Types of distractions**

In terms of their nature and causes, the types of disorders can be grouped as follows [11]:

2.3.1. **Over voltage.** Overvoltage is a disturbance due to the voltage in the electric power system that is greater than it should be. Overvoltage disturbances may occur due to external and internal conditions in the following systems:

- Internal conditions, this is mainly due to oscillations due to sudden changes in circuit conditions or due to resonance. For example, a link operation on no-load lines, sudden load changes, sudden disconnect operation due to line short circuit, and isolation failure.
- External conditions are especially due to lightning strikes. Lightning occurs due to the accumulation of electric charges, which results in the meeting of positive and negative charges. That meeting results in a voltage difference between a cloud, a positive charge, a negative charge, a cloud with a positive or negative charge, and the ground. If this voltage difference is high enough, there will be a jump of electric charge from cloud to cloud or from cloud to ground.

2.3.2. **Overload.** Overload is a disturbance that occurs due to energy consumption that exceeds the electrical energy generated at the generator. Load disturbances are common, especially in generators and power transformers. The characteristic of overload is the occurrence of overcurrent in the component. This overcurrent can cause excessive heating, which can cause damage to the insulation.

2.3.3. **Short circuit.** The short circuit is the occurrence of a voltage or non-voltage conductor relationship directly, not through the medium (load), which should be so that an abnormal current flow occurs (very large). A short circuit is a type of disturbance in electric power systems, especially in 3-phase airlines. However, all electrical equipment components are insulated with solid, liquid (oil), air, and gas insulation. However, due to service life, wear, mechanical stress and other causes, the insulation strength of electrical equipment can be reduced or even completely lost. This would easily lead to a short circuit. Several types of short circuit faults occur in 3-phase electric power systems, namely:

- Symmetric three-phase short circuit:
Three phases (L - L - L)  
Three phases to ground (3L - G) Unsymmetrical short circuit  
One phase to ground (1L - G)  
Interphase to ground (2L - G)  
Between phases (L - L)

2.4. Impendance of power transformer

The calculation of the impedance something transformer that taken is price reaction, while the prisoners are ignored because the price is small. To find the positive and negative sequence reactance values of the transformer in Ohm, it is calculated by the following equation [10]:

\[ X_T = X_T(\text{pu}) \times \frac{KV^2}{MVA} \]

Where:
- \( X_T \) = Transformer impedance [\( \Omega \)]
- \( X_T(\text{pu}) \) = transformer impedance [pu]
- \( KV \) = Primary side voltage of the transformer [kV]
- \( MVA \) = Transformer capacity [MVA]

2.5. Distance relay

The distance relay is used as the main protection on SUTT / SUTET and a backup for the section in front. The distance relay works by measuring the impedance (Z) of the transmission divided into several coverage areas, namely Zone-1, Zone-2, Zone-3, and is also equipped with teleportation (TP) to make protection work always fast and selective in its security area.

Information:
- Zone -1 = Area of Safety 1
- Zone -2 = Area of Safety 2
- Zone -3 = Area of Safety 3

2.5.1. Zone Determination 1. Zone 1 is also called the main protection of the distance relay, which is a protection that works without delay with a limited range of the conducting section itself. Considering the error factor (Percentage error) of CT, PT / CVT relay protection, safety margin, and network parameters, zone 1 has a range of 80-85% of the line impedance [12]. So that the calculation of the zone 1 impedance range can be stated as follows:

\[ Z_{\text{a1p}} = 0,8 \times Z_{L1} \Omega \]

2.5.2. Zoning 2. Zone 2 or also called remote backup protection on the distance relay, is a protection that is reserved for work if the main protection section in front of it fails to work. Zone 2 is generally set with a minimum range reaching the line impedance up to the Substation in front. (but not exceeding the smallest impedance of the transformer in the front GI) with a delay time of between 300 - 800 milliseconds. (depending on impedance range and coordination with time zone 2 ahead) [12]. Assuming errors such as the setting for Zone 1 are around 20%, the minimum and maximum settings for Zone 2 are as follows [13]:

\[ Z_{\text{L2}} = \text{Shortest next channel impedance} \]
\[ X_T = \text{Reactance of transformer in Zone 1} \] Selected the greatest value for Zone 2 impedance,
however does not exceed the impedance of the Zone 2 transformer. This is intended if there is a fault on the LV transformer, the distance relay does not work.

To determine the time for zone 2, the following can be considered:

- For the circumstance where $Zona_{2_{\text{max}}} > Zona_{2_{\text{min}}}$ then setting Zone 2 taken $t = 0.4$
- If the channel that is secured is much longer than the channel of the next section it will occur $Zona_{2_{\text{max}}} < Zona_{2_{\text{min}}}$. In such circumstances to get good selectivity, Zone 2 = $Zona_{2_{\text{min}}}$ with the time setting increased by one level ($t_2 = 0.8$ seconds)

2.6. Impedance read distance relay

In adjusting, first, the impedance value in the power (primary) system is determined. Secondary impedance is calculated by multiplying the CT and PT ratio in the equation [12]:

\[
PT = \frac{PT_{\text{primer}}}{PT_{\text{sekunder}}}, \quad CT = \frac{PT_{\text{primer}}}{CT_{\text{sekunder}}} \quad n1 = \frac{CT}{PT}
\]

Where:
- $n1$ = CT and PT ratio
- $CT$ = Current transformer ratio
- $PT$ = voltage transformer ratio so that the relay can select the impedance which is the secondary adjustment is as follows [1]:

\[
Z_{\text{rel}} = n1 \times Z_p
\]

Where:
- $Z_{\text{rel}}$ = Impedance the relay reads
- $n1$ = CT and PT ratio
- $Z_p$ = Adjustment impedance (primary)

2.7. Distance relay characteristics curves

2.7.1. Impedance characteristics. The characteristics of this relay have a circle with its center point in the middle. The weakness of this relay is that it is undirected because the two magnitudes being compared, namely the current and the voltage, are generated mechanically. Each coupling generated is independent of its phase. The relay will work for disturbances in front of and behind the relay. Therefore, this relay must be equipped with a directional relay to be used as a measuring relay [14].

Information:
- $Z1$ = Zone 1 impedance

Figure 3. Impedance characteristics [12].
### 2.7.2. Characteristics of Mho

The RX diagram can describe the characteristics of this distance relay as a circle passing through the center point. From the diagram, a relay's characteristics are directed so that the relay of this type does not need to add a rectifier element because the relay will only secure the disturbance in front of it. This type of distance relay can be shifted its working characteristics by entering the current factor in the auxiliary current transformer and the impedance in the characteristic voltage coil [14].

![Figure 4. Mho Characteristics](image)

### 2.7.3. Reactance Characteristics

In the characteristics of this distance relay, the impedance seen by the relay does not pay attention to the arc magnitude resistance because it is considered that the arc magnitude is almost the same. This relay is only for measuring reactive components and line impedance. The relay will work if the reactance seen by the relay is smaller than the regulated reactance. Arc resistance less influences this characteristic during a single-phase short circuit to the ground, so it is good to use for ground fault protection [14].

![Figure 5. Reactance Characteristics](image)

### Information:

- $Z_2$ = Zone 2 Impedance
- $Z_3$ = Zone 3 Impedance
- $Z_L$ = Line Impedance
- Directional = Additional directional relay

### 2.7.4. Quadrilateral Characteristics

The characteristics of this relay can be formed by determining the forward reach and resistive reach settings, each of which can be adjusted independently. The four relay limit settings, namely the upper limit, show the reactance range setting, then the left and right limits, namely the positive resistance range control and negative resistance, and the lower limit indicating directional.

Relays with this characteristic will work if the impedance measured by the relay is in the plane...
bounded by the four lines mentioned above. Quadrilateral has a wider range of resistance than the characteristic mho. This characteristic has advantages in terms of measuring impedance for ground disturbances. The ground disturbance has a high enough reactance caused by the arcing and impedance to the ground itself so that the disturbance reactance to the ground has a significant value [13].

![Quadrilateral characteristics](image)

**Figure 6.** Quadrilateral characteristics [13].

Information:
- \( Z_1 \) = Zone 1 impedance
- \( Z_2 \) = Zone 2 Impedance
- \( Z_3 \) = Zone 3 Impedance
- \( Z_L \) = Line Impedance

2.8. DigiSildent 15.1.7

*Digident*, the name stands for "Digital Simulation and Electrical Line Calculating Program." This digital version of DigiSILENT is the first power system analysis software in Indonesia that is integrated with a one-line graphical interface, one-line interactive program and includes drawing functions, editing capabilities, static relevance, and dynamic calculation features. The accuracy and validation of results obtained with this software have been confirmed in a large number and implemented by organizations involved in the design and operation of power systems [3].

3. Research methodology

This research begins with a literature study, namely as a first step to add insight into the protection relay settings. This research is intended to collect the required data, namely, single line diagrams, specifications of high voltage equipment (Current Transformer and Capacitor Voltage Transformer) channel data, data for setting the distance relay used in the line, data needed to complete this final project. Relay adjustment data were compared with standards, and simulations were carried out using DigiSilent 15.2.7 to see the relay work using PT PLN settings based on the time-distance relay curve. This comparison is found not under the standards in 15.1.7 to see fault zone on the characteristic curve with the distance relay with new tuning or the PT.PLN adjustment. Then the PT PLN adjustment is compared with the new adjustment.

4. Results

4.1. Equipment data

| No. | Bay   | Line   | CT Primer | CT Secunder | CVT Primer | CVT Secunder |
|-----|-------|--------|-----------|-------------|------------|--------------|
| 1.  | Bolok | Maulafa| 800       | 1           | 70000      | 100          |
|     |       | Maulafa| 800       | 1           | 70000      | 100          |
| 2.  | Maulafa| Bolok | 700       | 1           | 70000      | 100          |
|     | Bolok |       | 700       | 1           | 70000      | 100          |
Table 2. Line data.

| No. | Transmisi Line       | Type of Conductor | Length of Line |
|-----|----------------------|-------------------|----------------|
| 1.  | Bolok – Maulafa      | HAWK 240 mm²     | 14.37 kms      |
| 2.  | Maulafa - Naibonat   | OSTICH 152 mm²   | 35.97 kms      |

Table 3. Transformer data.

| No.  | Location             | Type of Trafo   | Impedance Magnitude |
|------|----------------------|-----------------|---------------------|
| 1.   | Bolok Substation’s   | UNINDO 30 MVA   | 12.25 %             |
| 2.   | Maulafa’s Substation | UNINDO 30 MVA   | 12.25 %             |
|      |                      | B&D 30 MVA      | 12.79 %             |

Table 4. Impedance of the conductor data.

| Bay Line                  | Z1 (Ω)            | Zo (Ω)          |
|---------------------------|-------------------|-----------------|
| Bolok – Maulafa (Z₄₁)     | 1.74224 + j4.83306 | 5.7511 + j16.33073 |
| Maulafa 1                 | 1.74224 + j4.83306 | 5.7511 + j16.33073 |
| Maulafa 2                 | 1.74224 + j4.83306 | 5.7511 + j16.33073 |
| Maulafa - Naibonat (Z₄₂) | 6.87526 + j12.6244 | 16.9076 + j41.4025 |
| Naibonat 1                | 6.87526 + j12.6244 | 16.9076 + j41.4025 |
| Naibonat 2                | 6.87526 + j12.6244 | 16.9076 + j41.4025 |

Table 5. Relay data.

| Bay Line                  | Type of Relay | Zone 1 | Zone 2 |
|---------------------------|---------------|--------|--------|
|                           |               | [Z] | Angle | t(s)  | [Z] | Angle | t(s)  |
|                           |               | Sec.ohm |        |       | Sec.ohm |        |       |
| Bolok -Maulafa Maulafa 1  | SIEMENS 7SA522| 6.127 | 71.4 | 0  | 16.468 | 71.4 | 0.4  |
|                           |                |          |        |   |          |       |
| Bolok -Maulafa Maulafa 2  | SIEMENS 7SA522| 6.127 | 71.4 | 0  | 16.468 | 71.4 | 0.4  |
|                           |                | 8       | 6     | 1  |          |       |
|                           | SIEMENS 7SA522| 6.127 | 71.4 | 0  | 16.468 | 71.4 | 0.4  |
|                           |                | 8       | 6     | 1  |          |       |
| Maulafa-Bolok Bolok 1    | GE D60         | 4.94  | 75.6 | 0  | 6.076  | 75.6 | 0.8  |
|                           |                |          |        |   |          |       |
| Maulafa-Bolok Bolok 2    | GE D60         | 4.94  | 75.6 | 0  | 6.076  | 75.6 | 0.8  |
|                           |                |          |        |   |          |       |

4.2. Distance relay reset (By Standard)

4.2.1. Transformer impedance. At the Bolok Substation and Maulafa Main Substation, there is a power transformer. At the Bolok Main Substation, there is one transformer. At the Maulafa Substation, there are two transformers. For the calculation of zone 2, the transformer itself takes the value of the transformer with the smallest impedance. In this case, the impedance value of the transformer at the Bolok Substation and the smallest impedance at the Substation is the same, so it can be calculated using the following equation:

\[ X_T = X_{T(pu)} \times \frac{KV^2}{MV2} \]
\[ = j0.1225 \times \frac{70^2}{30^2} \]
\[ = j0.1225 \times 163.33 \]
\[ = j20.0079 \Omega \]

\[ Zona 2_{trafo} = 0.8 (ZL_{L1} + 0.5X_T) \]
\[ = 0.8 (1.74224 + j4.83306 + 0.5 (j 20.0083)) \Omega \]
\[ = 0.8 (1.74102 + j14.83375) \Omega \]
\[ = 1.393792 + j11.869362 \Omega \]
\[ = 11.591319 \angle 83.30º \Omega \]
4.2.2. **CT and CVT Ratio**

a. The value of the CT and CVT ratio at Bolok Substation

To calculate the ratio value between CT and CVT, you can use equations 2.19, 2.20, and 2.21 as below:

\[
CT = \frac{CT\text{primer}}{CT\text{sekunder}} = \frac{800\ A}{1\ A} = 800\ C
\]

\[
PT = \frac{PT\text{primer}}{PT\text{sekunder}} = \frac{70000\ V}{100\ V} = 700\ C
\]

So that:

\[n_1 = \frac{CT}{PT} = \frac{800}{700} = 1.1428\]

b. The value of the CT and CVT ratio at the Maulafa substation

To calculate the ratio value between CT and CVT, you can use equations 2.19, 2.20, 2.21 as below:

\[
CT = \frac{CT\text{primer}}{CT\text{sekunder}} = \frac{700\ A}{1\ A} = 700\ C
\]

\[
PT = \frac{PT\text{primer}}{PT\text{sekunder}} = \frac{70000\ V}{100\ V} = 700\ C
\]

So that:

\[n_1 = \frac{CT}{PT} = \frac{700}{700} = 1\]

4.2.3. **Zone impedance adjustment**

a. Zone Setup 1

For Bolok - Maulafa bays can be obtained:

\[
Zona\ 1_p = 0.8 \times Z_l 1_p\ \Omega
\]

= 0.8 x (1.74224 + j4.83306) \Omega

= (1.3937 + j3.8665) \Omega

\[= 4.1099 < 70.18^\circ\ \Omega\]

\[
Zona\ 1_s = n_1 \times Zona\ 1_p\ \Omega
\]

= 1.1428 x (1.3937 + j3.8665) \Omega

= 4.698 < 70.18\^\circ \Omega

For Maulafa - Bolok bays can be calculated:

\[
\text{Zone1p} = 0.83 \times (Z11)\ \Omega
\]

= 0.83 x (1.74224 + j4.83306) \Omega

= (1.480904 + j4.001188) \Omega

\[= 4.26453 < 70.18^\circ\ \Omega\]

\[
\text{Zone1s} = n_1 \times (\text{Zone1p})\ \Omega
\]

= 1 x (1.480904 + j4.108101) \Omega

= 1.480904 + j4.001188 \Omega
For Bolok - Maulafa bays can be obtained:

\[ Z_{\text{min}} = 1.2 \times Z_{L_1} \]
\[ = 1.2 \times (1.74224 + j4.83306) \ \Omega \]
\[ = 2.0906088 + j5.79967098 \ \Omega \]
\[ = 6.165 < 70.18^\circ \ \Omega \]

\[ Z_{\text{max}} = 0.8 \times (Z_{L_1} + 0.8 \times Z_{L_2}) \]
\[ = 0.8 \times (1.74224 + j4.83306 + (0.8 \times (6.87526 + j12.6244))) \ \Omega \]
\[ = 0.8 \times (1.74224 + j4.83306 + (5.500208 + j10.0099)) \ \Omega \]
\[ = 5.7939584 + j11.874367 \ \Omega \]
\[ = 13.2125 < 63.99^\circ \ \Omega \]

For the zone 2 adjustment, a value comparison is carried out where the value used is the largest and does not exceed zone 2 of the transformer. So that zone 2 is used is zone 2 transformer with a large 11.591319 < 83.302º Ω.

\[ Z_{\text{max}} = Z_{\text{2, p}} \times n_1 \]
\[ = 1.1428 \times (1.393792 + j11.869362) \ \Omega \]
\[ = 1.5928 + 13.564764 \ \Omega \]
\[ = 13.657961 < 83.30^\circ \ \Omega \]

c. Noise zone readout

Nuisance zone reading is done by simulating abnormal conditions in the line. Abnormal conditions, in this case, short circuit disturbances are simulated using DigSilent as in Table 6. The simulations are carried out both for the line with the old relay settings and the new ones.

**Table 6.** Short circuit simulation.

| Types of fault     | Condition | Point of fault (Bolok direction – Maulafa) |
|--------------------|-----------|-------------------------------------------|
| 3 - phasa           | 1         | 10%                                       |
|                    | 2         | 50%                                       |
|                    | 3         | 90%                                       |
| 2 – phasa           | 1         | 10%                                       |
|                    | 2         | 50%                                       |
|                    | 3         | 90%                                       |
| 1 Phasa – ground    | 1         | 10%                                       |
|                    | 2         | 50%                                       |
|                    | 3         | 90%                                       |

From the simulation results of the brush connection noise as in Table 6, the results of the disturbance zone readings both with the old setting and the new setting can be seen in tables 7 and 8.
5. Discussion

The distance relay contained in the 70 kV Bolok - Maulafa transmission line uses two types of characteristic curves, namely the quadrilateral characteristic curve and the Mho characteristic curve. The use of each characteristic curve of the relay used in the Bolok - Maulafa 70 kV transmission line. The mho characteristic curve is used to describe the protection zone and show the fault points that occur for the type of phase disturbance phase, while the quadrilateral characteristic curve describes the zone of protection and shows the fault points that occur for the phase-to-ground fault type. The value of the adjustment placed on the relay affects the length of the relay's protection zone area. Comparison of the adjustment value by PT.PLN (Persero) and the new adjustment can be seen in Table 9.

Table 7. Readings of noise zones and fault impedance (Old).

| Type of Fault  | Type of Fault | Zone of Fault | Impedance of Fault |
|----------------|---------------|---------------|-------------------|
|                |               | Bolok’s Relay | Maulafa’s Relay   |
| 3 – Phasa       | 10%           | Zone 1        | Zone 1            |
|                 | 50%           | Zone 1        | Zone 1            |
|                 | 90%           | Zone 1        | Zone 1            | 0.5137<70.17º | 4.624<70.17º |
| 2- Phasa        | 10%           | Zone 1        | Zone 1            |
|                 | 50%           | Zone 1        | Zone 1            |
|                 | 90%           | Zone 1        | Zone 1            | 0.5522<71.50º | 4.9728<71.53º |
| 1 Phasa to      | 10%           | Zone 1        | Zone 1            |
| ground          | 50%           | Zone 1        | Zone 1            |
|                 | 90%           | Zone 1        | Zone 1            | 0.5237<77.16º | 4.5131<77.51º |

Table 8. Readings of noise zones and fault impedance (New).

| Type of fault  | Type of fault | Zone of Fault | Impedance of fault (Ω) |
|----------------|---------------|---------------|------------------------|
|                |               | Bolok’s Relay | Maulafa’s Relay        |
|                |               | Zone 1        | Zone 2                 |
| 3 – Phasa       | 10%           | Zone 1        | Zone 1                 |
|                 | 50%           | Zone 1        | Zone 1                 |
|                 | 90%           | Zone 2        | Zone 1                 | 0.5137<70.17º | 4.624<70.17º |
| 2- Phasa        | 10%           | Zone 1        | Zone 2                 |
|                 | 50%           | Zone 1        | Zone 1                 |
|                 | 90%           | Zone 2        | Zone 1                 | 0.5522<71.50º | 4.9728<71.53º |
| 1 Phasa to      | 10%           | Zone 1        | Zone 2                 |
| ground          | 50%           | Zone 1        | Zone 1                 |
|                 | 90%           | Zone 2        | Zone 1                 | 4.7749<71.67º | 0.5210<71.50º |

Table 9. Comparison of noise zone readings.

| Type of fault  | Point of fault (Bolok – Maulafa dericition) | Fault zone read by relay |
|----------------|---------------------------------------------|--------------------------|
|                | Bolok’s Relay | Old | New | Maulafa’s Relay | Old | new |
| 3 - phasa       | 10%           | Zone 1 | Zone 1 | Zone 1 | Zone 2 |
|                 | 50%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
|                 | 90%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
| 2 – phasa       | 10%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
|                 | 50%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
|                 | 90%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
| Phasa - ground  | 10%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
|                 | 50%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
|                 | 90%           | Zone 1 | Zone 1 | Zone 1 | Zone 1 |
In Table 9, we can see the difference in noise zona readings between the settings by PT. PLN and the new setup seem to have a difference. The difference in the adjustment value causes the different readings of the fault zone by the attached relay. From the 3 phase, short circuit fault simulation results at 10% point of Bolok to Maulafa direction, which is carried out to see the relay work when a disturbance occurs, both with PT.PLN settings and new settings, it can be seen that the location of the disturbance is depicted in the characteristic curve.

In Figure 7, it can be seen that the relay was found at the Maulafa Main Substation (Maulafa-Bolok bay conductor). The point of interference is in the zone 1 protection area. The relay found at Bolok Main Substation (Bolok - Maulafa delivery bay) is also in the protection area zone 1. The location of the disturbance point is in Figure 7 compared to Figure 8, which is a characteristic curve with settings that have been adjusted to the standard. It can be seen that the fault point is in the zone 2 protection area by the relay located at the Maulafa main substation (Maulafa - Bolok delivery bay) and the relay which is contained in the point of interference is in the protection area of zone 1. By using the standard, namely, in Figure 4.8, it can be said that the relay with the old setting is less selective in reading the existing disturbances because 10% of the length of the direction is Bolok - Maulafa is equal to 90% of the length of the lead in the direction of Maulafa - Bolok, so the zone read for the relay at the Maulafa Main Substation is zone 2.

6. Conclusion
New impedance adjustment value which conforms to the standard on Bolok bays - Maulafa in Zone 1 and 2 are 4,698 sec.Ω and 13,658 sec.Ω. Meanwhile, the new impedance adjustment value for the Maulafa - Bolok bay conductor in zone 2 is 4,264 sec.Ω with the difference in the distance relay settings by PT PLN and the new one. There is also a difference in the fault zone read by the relay with the respective settings.
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