Distance Relay Protection System Planning on Malang 150 kV Transmission Network Reconfiguration

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Abstract

This paper discusses the installation planning of distance relay protection systems in 150 kV Malang Raya transmission system reconfiguration. This study aims to minimize the disruption in the reconfiguration of Malang Raya transmission lines. The scenario of distance relay setting zones is divided into Pakis-Sutami substation, Sutami-Sengkaling substation, Sengkaling-Lawang substation, Lawang-Pakis substation. 3-phase fault scenarios with different fault locations according to the zone of protection. Based on the results of the simulation, Zone 1 scanned the disturbance at a distance of 27,616 km. Zone 2 scans disruption at a distance of 48.07 km. Zone 3 scans disruption at a distance of 59.29 km. With the installation of the distance relay protection system, it can be used as a reference to determine the distance or location of the disturbance.

Keywords
Transmission System, Protection System, Distance Relay, Tripping Time.

1. Introduction

Nowadays, electricity is a basic human need that must be met. More and more electronic and electrical equipment used by the public, industry, and public places, making the need for electrical energy every year is increasing. In Indonesia, it is estimated that growth in electricity demand will continue to increase following the 2018-2027 RUPTL of 6.9% [1]. Thus the process of electricity distribution must be kept sustained and in good quality.

The scenario of adding a 150 kV transmission lines requires improving the quality and reliability of the Malang main power system. With the increase in load and the addition of the 150 kV transmission line, then necessary to install a protection system to secure the network from fault and minimize the disruption that occurs. Based on [2] for medium and long transmission lines 150 kV and 70 kV must be protected with a distance relay scheme. Therefore, this study discusses the installation of distance relay in the scenario of adding a new 150 kV Malang transmission line that includes the Pakis-Sutami substation, the Sutami-Sengkaling substation, the Sengkaling-Lawang substation, the Lawang-Pakis substation.

Distance relays have a working principle based on the measurement of conductance impedance [3]. The conductance impedance felt by this relay is the result of the voltage sharing with the current from a circuit [4, 5]. The problem of measuring the impedance of the transmission system is divided into several areas of safety scope, namely zone-1, zone-2, and zone-3 because in the protection scheme the distance relay impedance size depends only on the length of the conduit which is affected by the interference at the relay point [6-9]. Besides, the distance relay protection system can minimize fault on the transmission line because of the short distance tripping time relay [10]. With the installation of this protection system, disturbances in the transmission network can be detected distance and location [11, 12]. The results of the design of this distance relay protection system will be recommended to the authorities.

2. Main Theory and Related Current Research

The scenario of adding a 150 kV transmission network needs to be done to improve the quality, reliability, and improvement of the Malang Raya main system. The scenario of adding transmission networks is done by adding a new 150 kV network to the Pakis-Sutami substation, the Sutami-Sengkaling substation, the Sengkaling-Lawang substation, and the Lawang-pakis substation. With the addition of the 150 kV transmission system network, it is necessary to install a protection system to secure the network from interference and minimize the disruption that occurs. The distance relay installation will be installed at the

Pakis-Sutami substation, the Sutami-Sengkaling substation, the Sengkaling-Lawang substation, and the Lawang-Pakis substation.

Research on the working principles of distance relays is being developed to observe how distance relay works with a variety of conditions, such as differences in the value of fault resistance, inter-line and line to ground fault, and a decline in the values of system frequency.

The author [13] states that distance relay with Quadrilateral characteristics show a more flexible protection system when a fault between the line to line to high resistance grounds occurs. The research was conducted on a short transmission line of 400 kV, 50 Hz and discusses adaptability of the distance relay with quadrilateral characteristics with different conditions of load, voltage, source of impedance, grid system impedance, and system frequency. The results of the simulation are plotted onto the R-X diagram to determine the distance relay with quadrilateral characteristics according to the stated conditions. Quadrilateral characteristics change slightly when there is a change in the value of grid impedance. However, the changes in the working principles occur very significantly if the value of the source impedance, system frequency, voltage, and loading systems change.

Authors [14] states that fault resistance can cause under-reach of working of the distance relay with Mho characteristics so that the fault is released in a long time. The establishment of the compensation method of the fault resistance using a two-terminal algorithm is presented to eliminate the effect of the values of the fault resistance of the distance relay protection zone so that the fallout points of the resistance is located exactly in the protection zone. The variable that can be determined is the distance of the fault, followed by the calculation of the value of the fault voltage, fault resistance, and the real value of resistance and reactance. The compensation value of the resistance is gained by reducing the real resistance value with the calculated fault resistance.

Authors [12] carried out a long transmission line modeling and calculation of fault impedance of three lines, two lines, and a single line to a ground fault according to the calculation formula of the value of fault impedance read on the distance relay to observe current and voltage waves when the fault occurs with distance fault of 50km, 100km, and 150km. The longer location of the fault from the protection zone, the greater the value of the fault impedance. Therefore, the points of the fault impedance based on the protection zone that has been set. The points of the impedance are in Zone 1, Zone 2, and Zone 3 as shown by the mho characteristics that have been plotted based on the impedance value (R-X) and the protection zone of the distance relay.

This study discusses the distance relay settings that will be installed on the new 150 kV transmission line in Malang Raya. With the installation of the distance relay, interference that occurs in the 150 kV Malang Raya transmission network can be minimized. The following equation calculates distance relay settings:

A. Distance Relay

- Determine CT and PT
  CT Ratio = 1200/5 Ampere
  PT Ratio = 750.000/100 Volt

  n 1 = CT ratio/PT ratio (1)

- Determine Zone 1, Zone 2, Zone 3
  Zone 1

  Zone 1 protection includes the main protection of protected lines that have directional properties. Zone 1 is able to protect 80% of the length of the transmission line, 20% to consider measurement errors in the current transformer, voltage transformer, and when adjusting the relay. From the above statement can be written equation by the formula as follows:

  $$Z_{1p} = 0.8 \times ZL_1 \quad (2)$$

  $$Z_{1s} = Z_{1p} \times n1 \quad (3)$$

  With : ZL_1 = impedance of the secured transmission line (Ohm)

  Zone 2

  Zone 2 protection area covers 15% - 20% of area that is not protected by zone 1, plus 50% for the next channel conductor. Zone 2 protection areas have the characteristics of recognizing the direction and setting with slowing time when operating. So the equation can be written in the following formula:

$Z_{2min} = 1.2 \text{ x } ZL_1$ (4)

$Z_{2max} = 0.8 \text{ x } (ZL_1 + (0.8 \text{ x } ZL_2))$ (5)

$Z_{2trafo} = 0.8 \text{ x } (ZL_1 + 0.5X_T)$ (6)

With:

ZL_1 = impedance of the secured transmission line (Ohm)

ZL_2 = impedance of the next secured transmission line (Ohm)

X_T = Transformer reactance in Zone 1

Zone 3

In contrast to the protection of Zone 1 and Zone 2, Zone 3 is directionless, so the determination of Zone 3 protection is measured from the residual conductor that is not protected by zone 2 for 50% and is still able to protect 25% up to the next channel with slower operating time (t3), then the equation is as follows:

$Z_{3min} = 1.2 \text{ x } (ZL_1 + ZL_2)$ (7)

$Z_{3max1} = 0.8 \text{ x } (ZL_1 + (1.2 \text{ x } ZL_2))$ (8)

$Z_{3max2} = 0.8 \text{ x } (ZL_1 + (0.8 \text{ x } (ZL_2 + (0.8 \text{ x } ZL_4))))$ (9)

$Z_{3trafo} = 0.8\ (ZL_1 + 0.8X_T)$ (10)

With:

ZL_1 = impedance of the secured transmission line (Ohm)

ZL_2 = impedance of the next secured transmission line (Ohm)

ZL_3 = Impedance of the next longest transmission line (Ohm)

X_T = Transformer reactance in Zone 1

- Determine of Time Delay

Zone 1 Delay
If interference occurs in the Zone 1, the relay will work instantly:
$T_1 = 0$ s (11)

Zone 2 Delay
If disruption occurs in the Zone 2, the relay will work with the following conditions:
$T_2 = 0.4$ s, If $Zone_{2min} > Zone_{2max}$ (12)
$T_2 = 0.8$ s, If $Zone_{2max} > Zone_{2min}$ (13)

Zone 3 Delay
If interference occurs in the Zone 3, the relay will work with the following conditions:
$T_3 = 1.2$ s, if $Zone_{3max1} > Zone_{3min}$ or $Zone_{3max2} > Zone_{3min}$ (14)

$$T_3 = 1.6 \text{ s, if } Zone_{3min} > Zone_{3max1} \text{ or } Zone_{3min} > Zone_{3max2} \quad (15)$$

3. Method

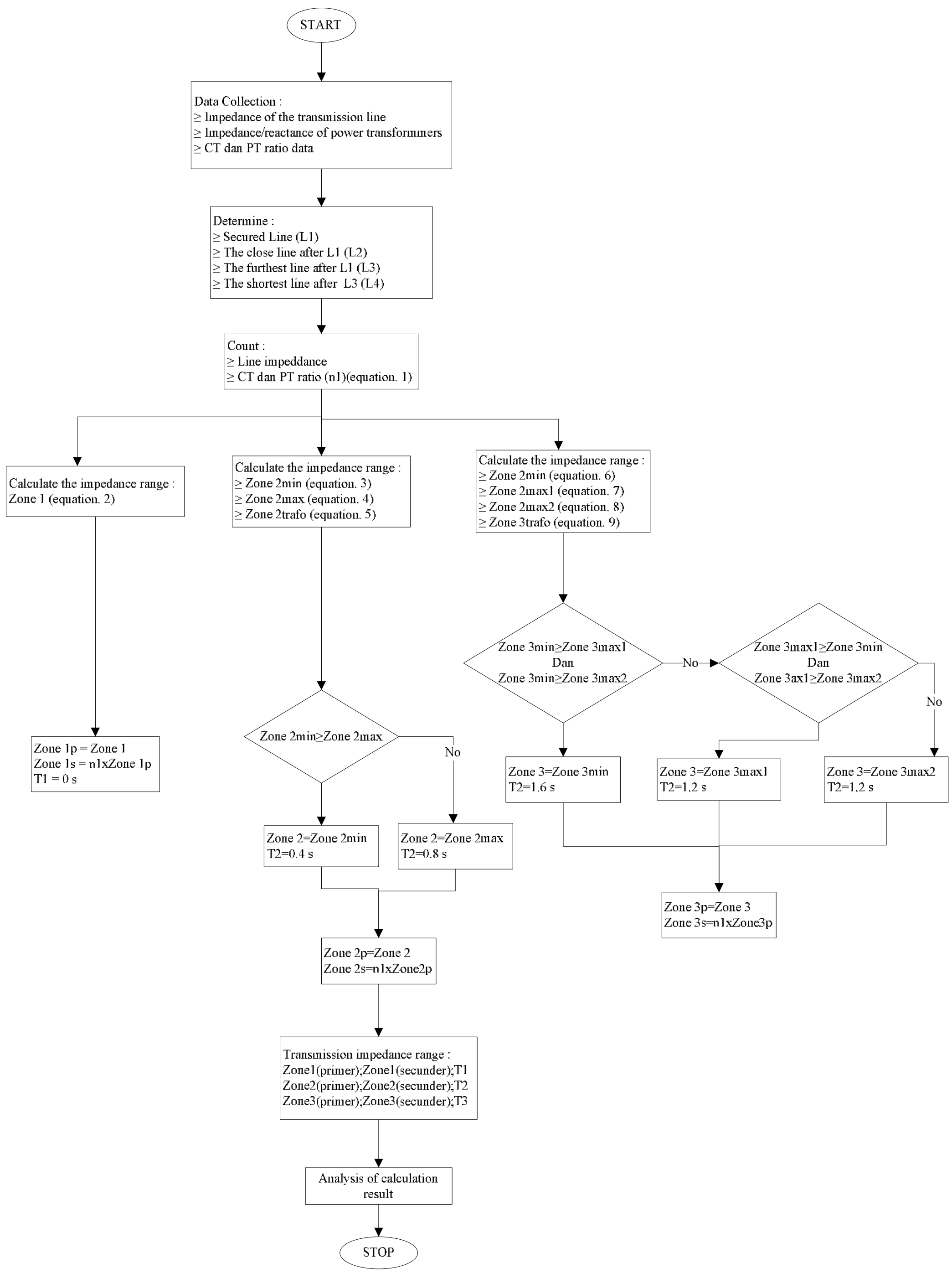

Figure 1. Flow Chart Calculation of Relay Settings for Transmission Distance 150 kV Malang Raya

4. Result

The results of distance relay setting impedance calculations are used to find out the range 1, Zone 2, and Zone 3 impedance values. In addition, the results of the setting will be used to determine the distance of the disturbance and the value of the interference resistance in the simulation.

4.1 Research Data

The data used in this study were obtained from PT. PLN (Persero). Following is the single Line Transmission Line Diagram 150 kV Malang Raya

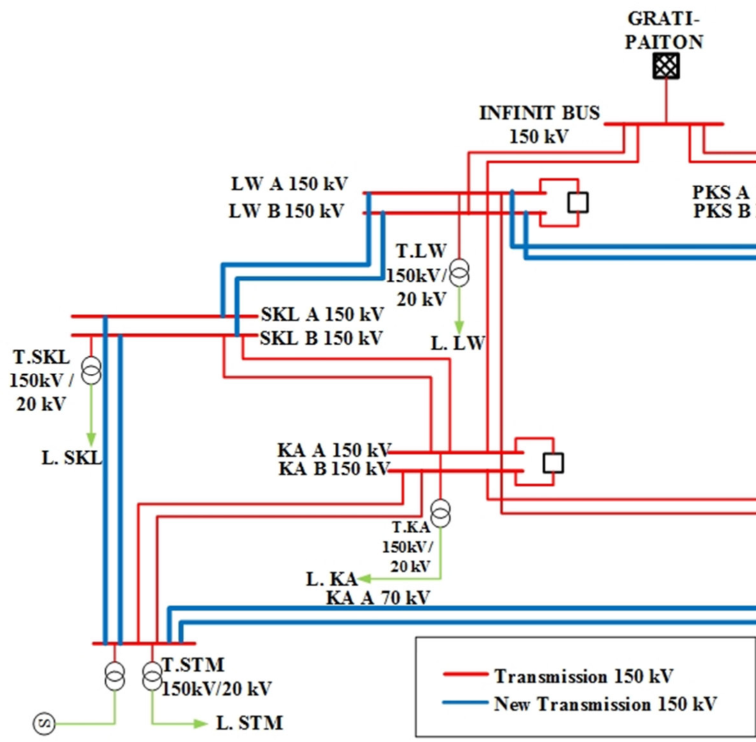

Figure 2. Single Line 150 kV Transmission Line Diagram

Figure 2 shows the 150 kV Malang transmission network, where the red color shows the Malang 150 kV old transmission network and the blue color shows the Malang 150 kV transmission network. The distance relay protection system will be installed on the new 150 kV Malang transmission network in blue.

4.2 Range of the Protection Zone on the 150 kV Malang Raya Transmission Line

Calculation of distance relay settings for 150 kV Malang Raya transmission line is done by determining the main channel to be protected. Channels selected where the Pakis substation, the Sutami substation, the Sengkaling substation, the Sengkaling substation, the Lawang substation. To calculate the impedance value of the protected transmission line protection that covers the zone are L1, L2, L3, and L4. Where:
L1 = Main transmission line protected (Pakis-substation Pakis-substation Sutami)
L2 = Short transmission line in front of L1 (Sutami substation-Sengkaling substation)
L3 = L2 = (Sutami substation-Sengkaling substation)
L4 = the shortest transmission line in front of L3 (Sengkaling substation-Lawang substation)

4.3 Calculation of Distance Rele Settings

In determining distance relay settings an electrical power system analysis is needed. For this reason, we need data relating to determining distance relay settings with the data below:

1. Data of CT Ratio and PT Ratio
   Current and power transformer data for 150 kV transmissions in Malang Raya.
   Known: CT Ratio = 1200/5 A
   PT Ratio = 150000/100 V
   Using equation (1), the ratio of CT and PT is obtained:
   n1 = CT ratio/PT ratio

n1 = 0.16

2. Impedansi Scope
   - Zone 1
     Known:
     ZL_1 = (2,34 + j6.62)
     n1 = 0.16
     The solution for zone 1 uses equations (2) and (3)
     Z_{1p} = 0.8 x ZL_1
     Z_{1p} = 0.8 x (2,34 + j6.62)
     Z_{1p} = 1,872 + j5,296
     Z_{1p} = 5,617 < 79,307°

     Z_{1s} = Z_{1p} x n1
     Z_{1s} = 1,872 + j5,296 x 0.16
     Z_{1s} = 0.299 + j0.847
     Z_{1s} = 0.898 < 70,55°

   - Zone 2
     Known:
     ZL_1 = (2,34 + j6.62)
     ZL_2 = (2,09 + j5,43)
     n1 = 0.16
     The solution for zone 2 using equations (4) and (5) is obtained:
     Z_{2min} = 1.2 x ZL_1
     Z_{2min} = 1.2 x (2,34 + j6.62)
     Z_{2min} = 2,808 + j7,944
     Z_{2min} = Z_{1s} = 8,425 < 70,645° Ohm

     Z_{2max} = 0.8 x (ZL_1 + (0.8 x ZL_2))
     Z_{2max} = 0.8 x ((2,34 + j6.62) + (0.8 x (2,34 + j6.62)))
     Z_{2max} = 2,136 + j9,532
     Z_{2max} = 9,768 < 77,369° Ohm

     Z_{2trafo} = 0.8 x (ZL_1 + 0.5X_T)
     Z_{2trafo} = 0.8 x ((2,34 + j6.62) + 0.5 x j22,96)
     Z_{2trafo} = 1,872 + j14,48
     Z_{2trafo} = 14,60 < 82,63° Ohm

     $Z_{2primer}$ = Z_{2max}
     $Z_{2primer}$ = 9,768 < 77,369° Ohm

     $Z_{2sekunder}$ = n1 x $Z_{2primer}$
     $Z_{2sekunder}$ = 0.16 x (1,872 + j14,48)
     $Z_{2sekunder}$ = 0,431 + j1,525
     $Z_{2sekunder}$ = 1,562 < 77,359° Ohm

   - Zone 3
     ZL_1 = (2,34 + j6.62)
     ZL_2 = (2,09 + j5,43)
     ZL_4 = (1,00 + j2,6)
     n1 = 0.16
     The solution for zone 3 using equation (7), (8), (9), dan (10) is obtained:
     Z_{3min} = 1.2 x (ZL_1 + ZL_2)
     Z_{3min} = 1.2 x ((2,34 + j6.62)+ (2,09 + j5,43))
     Z_{3min} = 5,316 + j14,46
     Z_{3min} = 15,406 < 69,814° Ohm

     Z_{3max1} = 0.8 x (ZL_1 + (1.2 x ZL_2))
     Z_{3max1} = 0.8 x ((2,34 + j6.62) + (1.2 x (2,09 + j5,43)))

$Z_{3max1} = 3{,}878 + j10{,}508$
$Z_{3max1} = 11{,}200 < 69{,}743° \text{ Ohm}$

$Z_{3max2} = 0.8 \text{ x } (ZL_1 + (0.8 \text{ x } (ZL_2 + (0.8 \text{ x } ZL_4))))$
$Z_{3max2} = 0.8 \text{ x } ((2{,}34 + j6.62) + (0.8 \text{ x } ((2{,}09 + j5{,}43) + (0.8 \text{ x } (1{,}00 + j2{,}6)))))$
$Z_{3max2} = 3{,}721 + j10{,}102$
$Z_{3max2} = 10{,}766 < 69{,}776° \text{ Ohm}$

$Z_{3trafo} = 0.8\ (ZL_1 + 0.8X_T)$
$Z_{3trafo} = 0.8\ ((2{,}34 + j6.62) + 0.8 \text{ x } j22{,}96)$
$Z_{3trafo} = 1{,}872 + j19{,}990$
$Z_{3trafo} = 20{,}077 < 84{,}65° \text{ Ohm}$

$Z_{3primer} = Z_{2max1}$
$Z_{3primer} = 11{,}200 < 69{,}743° \text{ Ohm}$

$Z_{3sekunder} = n1 \text{ x } Z_{3primer}$
$Z_{3sekunder} = 0.16 \text{ x } (3{,}878 + j10{,}508)$
$Z_{3sekunder} = 0{,}620 + j1{,}681$
$Z_{3sekunder} = 1{,}791 < 69.75° \text{ Ohm}$

3. Determine The Time Delay
   - Zone 1 Delay
     If interference occurs in a zone 1 area, the relay will work instantaneously, T1 = 0s.
   - Zone 2 Delay
     Based on the above conditions, setting the impedance range in zone 2 = Zona2max> Zona2min, so the delay time is selected: T2 = 0.8 s.
   - Zone 3 Delay
     Based on the above conditions, setting the impedance range in zone 3 = If Zone3max1> Zone3min or Zone3max2> Zone3min, so the delay time is selected: T3 = 1.2 s.

4.4 Simulation Result

In simulations, the type of distance relay uses Mho characteristics. In the impedance diagram R-X is a circle where the diameter of the circle intersects the center point of the coordinate system and the size of the diameter represents the range and phase angle settings of the Mho characteristic. The range and angle angle settings of the characteristic Mho can be set the same as the impedance of the protected transmission line. Rele the distance to the Mho characteristic will work if the measured impedance is a circle. To find out the working distance relay on the 150 kV Malang Raya transmission line based on the calculated protection zone settings can be seen in the picture:

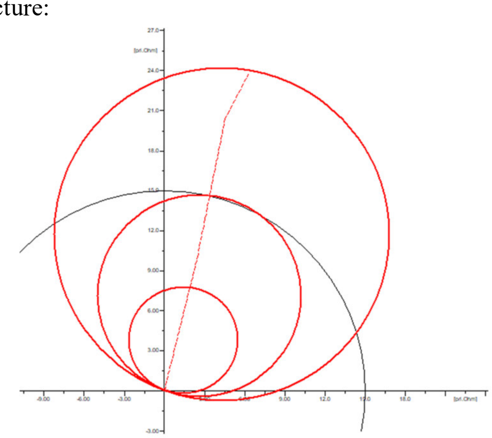

Figure 3. Initial Conditions Before Interference Occurs

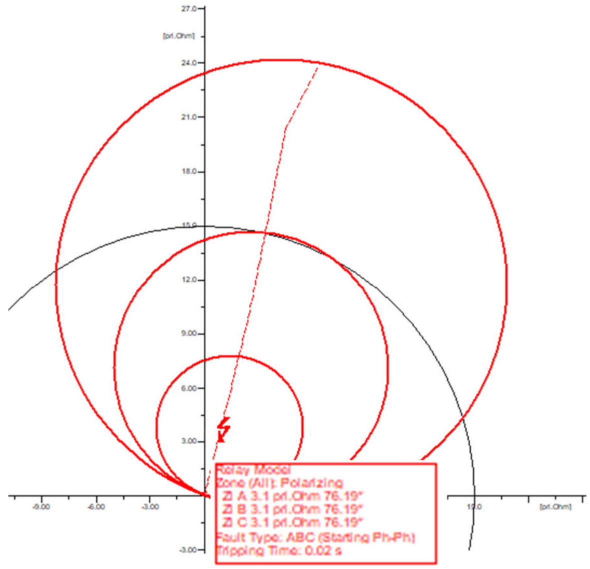

Figure 4. Conditions when disturbances occur in Zone 1 (Substation of Pakis-Substation Sutami)

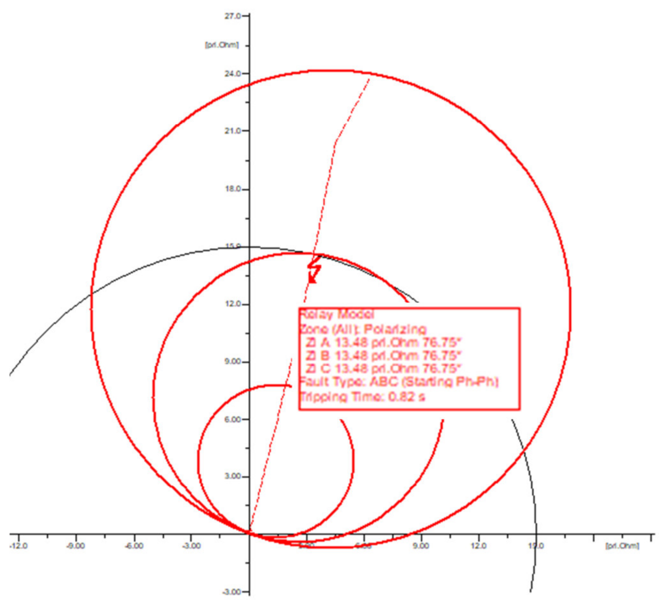

Figure 5. Condition when disturbance occurs in Zone 2 (Sutami substation and Sengkaling substation)

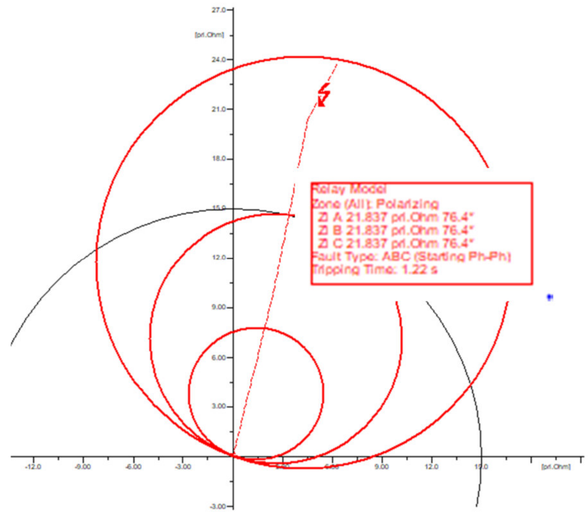

Figure 6. Conditions when disturbances occur in Zone 3 (Sengkaling Substation - Lawang Substation)

Figure 3 shows the region and channel length lines. Where, the area includes Zone 1, Zone 2, and Zone 3. The smallest circle indicates the Zone 1 region, the middle circle is the Zone 2 area, and the large Circle is the Zone 3 region.

Figure 4 is a network condition when a disturbance occurs in the Zone 1 region (Pakis substation-Sengakaling substation) and the disturbance occurs at a distance of 27,616 km. The simulation shows that there is a three-phase disturbance and shows an instant tripping time of 0.02 s and a phase angle of 76.19 degrees. The tripping time results in the simulation are in accordance with the calculation results. With these results it can be concluded the simulation results are in accordance with the results of the calculation of distance relay settings.

Figure 5 is a network condition when a disturbance occurs in the Zone 2 region (Sengkaling substation - Sutami substation). Disturbances occur at a distance of 48.07 km and the impedance value read by the relay is in the circle zone of Zone 2. With the occurrence of three phase disturbance in Zone 2, the relay sends a trip signal to the PMT with a tripping time of 0.82 s and the phase angle at 76.75 degrees. The tripping time results in the simulation were 0.82 s in accordance with the calculation results of 0.8 s. With these results it can be concluded the simulation results are in accordance with the results of the calculation of distance relay settings.

In Fig. 6 the conditions where the network disruption occurs in the Zone 3 region (Sutami substation-Lawang substation). Disturbances occur at a distance of 59.29 km and the impedance value read by the relay is in the zone, zone of Zone 3. With the occurrence of three phase disturbance in Zone 3, the signal sends a trip signal to the PMT with a trip time of 1.22 s and a phase angle of 76.4 degrees. The tripping time results in the simulation of 1.22 s correspond to the calculation results of 1.2 s. With these results it can be concluded the simulation results are in accordance with the results of the calculation of distance relay settings.

5. Conclusion

The results of the calculation and simulation of planning the installation of distance relay protection systems in the 150 kV Malang Raya transmission system is in accordance with the standard settings of the IEEE and ESDM Minister Regulation No. 03, 2007. The distance relays, protection system which is divided into three regions of the protection zone, namely the Pakis-Sutami substation, the Sutami-Sengkaling substation, the Sengkaling-Lawang substation, the Lawang-Pakis substation. Interference during simulation of scenarios with three different locations using three phase interferences. Zone 1 scanned disruption at a distance of 27,616 km with a tripping time of 0.02 s. Zone 2 scanned disruption at a distance of 48.07 km with a tripping time of 0.82 s. Zone 3 scanned disruption at a distance of 59.29 km with a tripping time of 1.22 s. Based on the calculation and simulation results, it is found that the impedance of interference and tripping time can be used as a reference to determine the distance or location of the disturbance from the protection center.

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