Analysis on Distance Relay Setting and Coordination at 150 KV High Voltage Transmission Line Kentungan Godean Bantul Semanu

Yusnan Badruzzaman and Afrizal Fawaid Fasihfauzi Ahmad
D3 Electrical Engineering Study Program, Electrical Engineering Department, Semarang State Polytechnic, Jl. Prof. H. Soedarto, SH Tembalang Kota Semarang 50275, Indonesia

Keyword: Distance Relay, Setting, Impedance, Coordination.

Abstract: High voltage power lines of 150 kV are one part of the electric power transmission system that has a fairly large potential for disturbance. The relevancy of a protection system on the High Voltage Power Lines of 150 kV. Distance relays are commonly used as the main protection of device on high-voltage power lines of 150 kV. Determining the distance relay setting requires calculating the zona impedance value and coordination, as well as simulating short circuit faults on each line to determine each distance relay operation. The method used is a comparative method that compares the calculation results with the settings from PLN and is assisted by the DigSILENT software to make it easier to analyze. The results of calculations and simulations are compared with setting from PLN. From this comparison, it is obtained the settings form PLN got zona-3 overlapping at Substation Kentungan in the direction of Godean with zona-3 Substation Godean in the direction of Substation Bantul, the selection of zona impedance values is not optimal in zona-2 Substation Godean in the direction of Bantul, zona-3 Substation Semanu in the direction of Bantul and zona -3 Substation Bantul Arah GI Godean, and zona-1 Substation Kentungan in the direction of Godean does not reach 80% of the main line.

1 INTRODUCTION

An electric power system consists of three main parts, namely power generation, transmission system and distribution system. The transmission system is an important part in the distribution of electrical energy from power plants to load centers or consumers. The long distance between the power plant and the load center makes the transmission system have the potential for large disturbances. Disturbances that occur can be caused by system errors, as well as non-system disturbances such as natural disturbances such as lightning strikes, fallen trees, and storms. The fault causes a short circuit of three phases, three phases to ground, two phases, two phases to ground and one phase to ground.

The protection system is mandatory in the electric power system in order to secure equipment and separate disturbed areas. A very vital component in the protection system is the relay. The protection relay is one of the main components in the electric power system that can have a major impact on the electric power system. The protection relay will identify a disturbance in the system by measuring the electrical quantity that is read by a measuring instrument which is always read in normal or fault conditions. The relay will instruct the PMT to trip to cut off electricity if it detects a fault condition. One of the protection relays that are often used is the distance relay which protects the transmission from short circuit interference.

Distance relays are usually used as the main safety of overhead lines on transmission networks both at 150 kV and 500 kV voltages. The way the distance relay works is to use the current and voltage measurements obtained from current transformers and voltage transformers to determine the impedance value of a transmission line. The distance relay will work if the impedance value read is less than the relay setting value. If the read impedance value exceeds the setting value, the distance relay will not work.

Setting the distance relay greatly affects the reliability of the relay itself, with the right setting value, the distance relay can work optimally and quickly in separating disturbed parts from other parts that are still healthy and at the same time securing healthy parts from damage or greater losses. .

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Therefore, the value of the distance relay setting must be considered properly so that the relay can work optimally

2 RESEARCH METHODS

2.1 Research Step

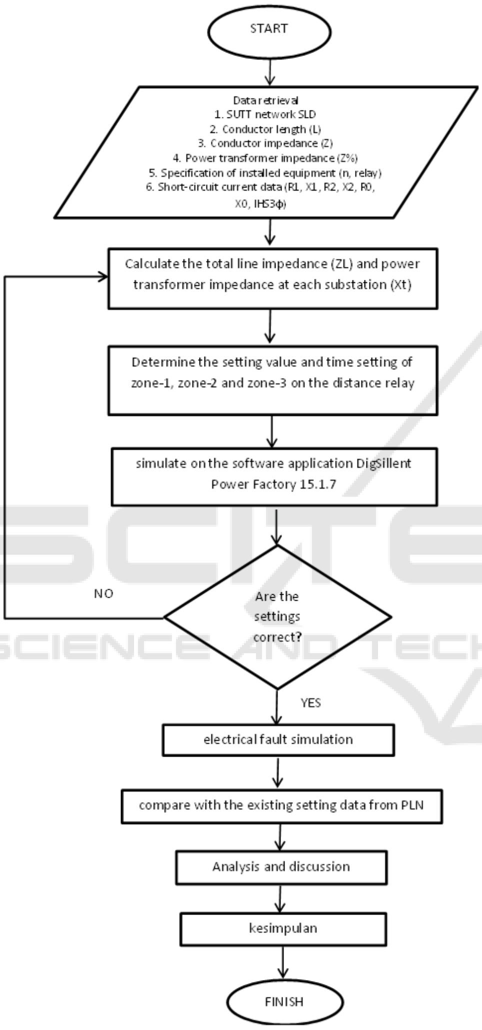

Figure 1: Diagram Alir Penelitian.

2.2 Research Data

There are 6 distance relays to protect the studied channel. The relays include GI Kentungan arag Godean, GI Godean to Bantul, GI Godean to Kentungan, GI Bantul to Godean, GI Bantul to Semanu, and GI Semanu to Bantul. To be able to calculate the setting, the following data is needed for the conductor.

Table 1: Conductor Data.

Line	Length (km)	Positive Sequence Impedance (Ω/km)	Zero Sequence Impedance (Ω/km)
Kentungan - Godean	9,1771	0,137 + j 0,3966	0,287+j 1,19
Godean - Bantul	13,211	0,137 + j 0,3966	0,287+j 1,19
Bantul - Semanu	39,043	0,137 + j 0,3966	0,287+j 1,19

To change the value on the primary side of the conductor into the value of the relay side, the ratio of the measurement tool is needed as follows.

Table 2: Ratio of Measurement Tools.

Substation	Protection Direction Ratio	Measurement	Transformer
Kentungan	Godean	CT	800/1 A
		CVT	150.000/100V
Godean	Kentungan	CT	600/1 A
		CVT	150.000/100V
	Bantul	CT	600/1 A
		CVT	150.000/100V
Bantul	Godean	CT	1000/1 A
		CVT	150.000/100V
	Semanu	CT	500/1 A
		CVT	150.000/100V
Semanu	Bantul	CT	500/1 A
		CVT	150.000/100V

In setting the distance relay also consider the impedance of the power transformer in the front substation. The following is the power transformer impedance data at each substation:

Table 3: Power Transformer Impedance Data.

Substation	Power Transformer	Impedance (pu)
Kentungan	Trafo 2	11,93 %
	Trafo 3	12,06 %
	Trafo 4	12,13 %
Godean	Trafo 1	12,25 %
	Trafo 2	12,11 %
Bantul	Trafo 1	11,92 %
	Trafo 2	11,51 %
	Trafo 3	11,86 %
Semanu	Trafo 1	12,18 %
	Trafo 2	11,31 %

The distance relay works based on the read impedance. If the read impedance is less than the setting impedance, the relay will work, but if the read impedance is more than the setting impedance, the relay will not work. To be able to determine the setting on the distance relay, the following equation is used.

1. Total Impedance of Conductor
In determining the setting required the total line impedance obtained from the equation:

$$ZL = Z \times L \quad (1)$$

Where:
ZL = Total Conductor Impedance (Ω)
Z = Impedance of conductor (Ω/km)
L = conductor length (km)

1. Power Transformer Impedance

Setting the distance relay must pay attention to the impedance of the power transformer at the front substation. The data taken from PLN is still in the form of pu, so it must be converted into ohms with the equation:

$$Xt = \frac{Zt\% \times V^2}{S} \quad (2)$$

Where:
Xt = Transformer impedance (Ω)
Zt = transformer impedance (pu)
V = nominal voltage (kV)
S = Transformer capacity (MVA)

1. Ratio of CT and CVT
To change the impedance that is read on the primary side, it is necessary to transform the impedance to the relay side using the existing CT and CVT ratios with the equation:

$$n = \frac{k\,CT}{k\,CVT} \quad (3)$$

Where:
n = Ratio of measuring tool
kCT = CT ratio
kCVT = CVT ratio

1. Setting Zone-1
To determine the impedance setting zone-1 can use the following equation:

$$Zone\text{-}1 = n \times 0.8 \times ZL1 \quad (4)$$

Where:
n = Ratio of measuring tool
ZL1 = Total impedance of main conductor
Zone-1 working time also needs to be set with a working time of 0 seconds (instant)
2. Setting Zone-2
To determine the impedance setting for zone-2, you can use the following equation:

$$Zona\text{-}2_{min} = n \times 1{,}2 \times ZL1 \quad (5)$$

$$Zona\text{-}2_{mak1} = n \times 0{,}8\,(ZL1+0{,}8.ZL2) \quad (6)$$

$$Zona\text{-}2_{mak2} = n \times (ZL1+0{,}5Xt) \quad (7)$$

Where:
n = Ratio of measuring tool
ZL1 = Total impedance of main conductor
ZL2 = Total impedance of front GI shortest conductor
Xt = Power transformer impedance

From equations (5) and (6) the largest value is chosen but it should not exceed the impedance value (7). Zone-2 working time also needs to be set with a working time of 0.3-0.8 seconds.

1. Setting Zone-3
To determine the impedance setting for zone-3, you can use the following equation:

$$Zona\text{-}3_{min} = n \times 1{,}2\,(ZL1+ZL3) \quad (8)$$

$$Zona\text{-}3_{mak} = n \times 0{,}8\,(ZL1+0{,}5.Xt) \quad (9)$$

Where:
n = Ratio of measuring tool
ZL1 = Total impedance of main conductor
ZL3 = Total impedance of front GI longest conductor
Xt = Power transformer impedance

From equations (5) and (6) the largest value is chosen. Zone-3 working time also needs to be set with a working time of 0.8-1.6 seconds.

3 RESULTS AND DISCUSSION

3.1 Distance Relay Setting

From the results of calculations with the equations in chapter 2, the results of the settings are as follows:

Table 4: Calculation Results of Distance Relay Settings.

Substation	Protection Direction	Zone	Impedance (Ω)	Working Time
Kentungan	Godean	Zona-1	1,643	0 s
		Zona-2	3,535	0,4 s
		Zona-3	11,256	1,6 s
Godean	Kentungan	Zona-1	1,232	0 s
		Zona-2	2,753	0,4 s
	Bantul	Zona-1	1,774	0 s
		Zona-2	3,405	0,4 s
		Zona-3	10,524	1,2 s

Table 4: Calculation Results of Distance Relay Settings (cont.).

Substation	Protection Direction	Zone	Impedance (Ω)	Working Time
Bantul	Godean	Zona-1	2,956	0 s
		Zona-2	4,599	0,4 s
		Zona-3	14,939	1,2 s
	Semanu	Zona-1	4,369	0 s
		Zona-2	6,553	0,4 s
Semanu	Bantul	Zona-1	4,369	0 s
		Zona-2	6,553	0,4 s
		Zona-3	9.987	1,6 s

From the table, the impedance setting and working time of zone-1, zone-2, and zone-3 are obtained for each relay for each substation.

3.2 R-X Plot Diagram

The setting results that have been obtained are entered in the DigSILENT software simulation program and an R-X Plot Diagram is obtained as shown in the following figure:

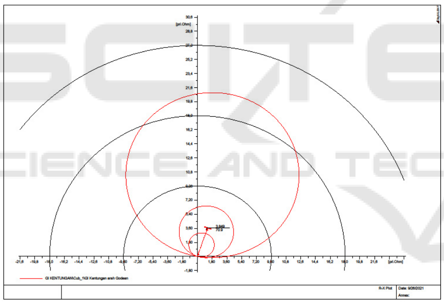

Figure 2: R-X Plot Diagram of GI Distance Relay Kentungan direction Godean.

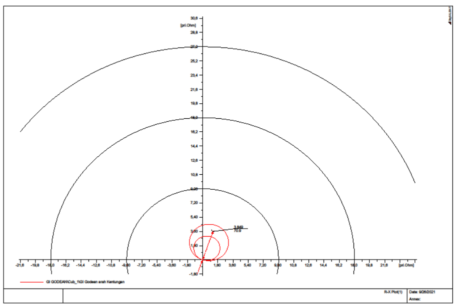

Figure 3: R-X Plot Diagram of GI Godean Distance Relay in Kentungan direction.

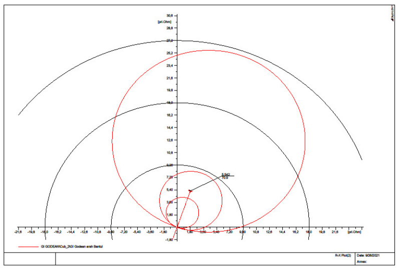

Figure 4: R-X Plot Diagram of the Godean GI Distance Relay in the direction of Bantul.

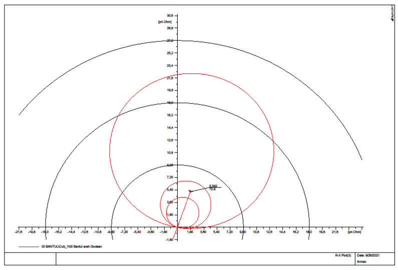

Figure 5: R-X Plot Diagram of the Distance Relay of GI Bantul in Godean direction.

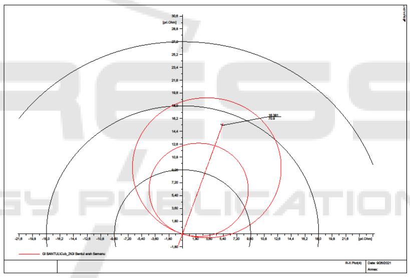

Figure 6: R-X Plot Diagram of the Distance Relay of GI Bantul in Semanu direction.

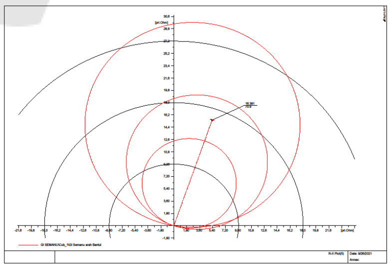

Figure 7: R-X Plot Diagram of the Semanu GI Distance Relay in Bantul.

From Figure 3 to Figure 8, the protection area of each zone is shown in a circle.

3.3 Time Distance Diagram

The following is the Time-Distance diagram of the simulation results using the DigSILENT software.

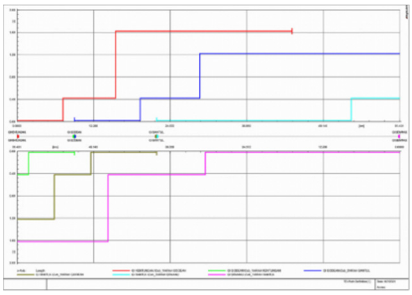

Figure 8: Time-Distance Diagram Setting Calculation Results.

From Figure 8, it can be seen that the distance relay coordination between substations is correct.

3.4 Comparison with PLN's Existing Settings

Setting the calculation results in theory compared to the existing PLN settings can be seen in the following table:

Table 5: Comparison of Calculation Settings with PLN.

Substations	Direction of Protection	Zone	Calculation Setting (Ω)	PLN Setting (Ω)
Kentungan	Godean	Zona-1	1,643	1,55
		Zona-2	3,535	3,34
		Zona-3	11,256	11,23
Godean	Kentungan	Zona-1	1,232	1,232
		Zona-2	2,753	14,151
	Bantul	Zona-1	1,774	1,774
		Zona-2	3,405	4,169
		Zona-3	10,524	10,637
Bantul	Godean	Zona-1	2,956	3,138
		Zona-2	4,599	4,841
		Zona-3	14,939	7,7
	Semanu	Zona-1	4,369	4,567
		Zona-2	6,553	8,194
Semanu	Bantul	Zona-1	4,369	4,369
		Zona-2	6,553	6,553
		Zona-3	9.987	14,082

From the comparison above, it can be seen that there are existing PLN settings that are less than optimal and there is still overlapping in the distance relay of the Kentungan GI in the Godean direction, the Godean GI in the Bantul direction, the Bantul GI in the Godean direction, and the Semanu GI in the Bantul direction.

4 CONCLUSION

1. a. Zone-1 range of distance relay protection is 80% of the main line length with formula 0.8 × ZL1.
   b. The protection area from zone-2 must reach the substation in front of it and take into account the transformer impedance, which is 50% of the transformer impedance of the substation in front of it with the formula ZL1 + 0.5 Xt, and in determining the impedance value choose the largest value between zone-2 at least 120 % main line (1.2 × ZL1) with zone-2 maximum (0.8 (ZL1 + 0.8 ZL2) which pays attention to the shortest line connected to the substation in front of it.
   c. The protection area from zone-3 must cover 2 (two) substations in front of it, and in determining the impedance value choose the largest value between zone-3 at least (1,2 (ZL1 + ZL3) which considers the longest line connected to the substation in front of it, with a maximum-3 zone (0.8 (ZL1 + 0.5 Xt) with and considering the transformer impedance at the front substation.
   d. The choice of working time for each zone must be considered to obtain good coordination to avoid overlapping and optimize the performance of the protection zone on each secured channel, namely in zone-1 working 0 seconds (instant), in zone-2 working 0.3 - 0.8 seconds (as needed) and in zone-3 it works 0.8 – 1.6 seconds (as needed).
2. In the PLN settings, it is found that the protection zone is less than optimal and overlapping, namely at
   a. zone-3 GI Kentungan is directed to GI Godean with zone-3 GI Godean to GI Bantul with a working time of 1.6 seconds, so it needs to be reset.
   b. In the PLN setting, it was found that zone-1 did not reach 80% of the main line, namely the distance relay from GI Kentungan to GI Godean with a range of 75%, so resetting was necessary.
   c. The value of the PLN zone-3 setting on the distance relay of the Semanu GI to the Bantul GI is 4.095 less than the calculation results, because in determining the longest line (L3) connected to the substation in front of it, data is not in accordance with current conditions, so the performance of the protection zone is not optimal.

d. The PLN setting for zone-2 relay distance from the Godean GI to the Bantul GI direction is greater than 0.764 because it does not consider the High Voltage Cable Channel (SKTT) as the shortest line, thus allowing overlapping with the Bantul GI zone-2 in the Wirobrajan GIS direction using SKTT.
e. The PLN setting value for zone-3 relay distance from the Bantul GI to the Godean GI is 7.293 less than the calculation results, because in determining the impedance value for zone-3, the zone-3mak does not take into account the transformer impedance.

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