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An Improved Protection Of High Voltage Air Line Using Differential Relays

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ABSTRACT
A static electrical device is like a power transformer, one of the functions of which is to transfer one power circuit to another circuit, either changing the voltage without having to change the frequency. This paper described a Protection is a system in electricity and has a function as an isolate, breaker and separator if there is a disturbance. The working principle of the differential relay is to compare the vector I1 of the primary side current with I2 of the secondary side current. "The results of the mathematical calculation of the setting current for the differential current obtained are 0.0961865394 A and this is different from the setting current installed in the differential relay on the power transformer of 1 substation, namely 0.3 A."

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INTRODUCTION

Currently, technological developments for the benefit of individuals are very important in this modern era. Along with technological developments, electrical energy sources are the most important element in this modern era and are really needed by society, especially industry. The substation is a power transformer, one of which must be protected from interference. Disruptions often occur when the distribution of electrical power is large enough to cause a break in the continuity of the load's electrical power .

The distribution of electrical energy from production centers is very far from the load/consumer centers (power plants). The use of distribution systems with different operating voltage systems reduces line losses. The voltage system selection occurs in another channel for the transmission of electrical energy by increasing and decreasing the voltage from the generating center to the substation via a transformer, which is then distributed to consumers according to the consumer. These disturbances cause voltage and current disturbances. Large short circuit currents can cause leaks, thus changing the operation of the entire electrical system and disrupting or causing power failure.

The substation has important equipment for electricity distribution, a very important equipment is the transformer. A transformer is a device that converts energy from high voltage to low voltage or vice versa for distribution to the community. Substation transformers are the most expensive and important assets for customers in distributing electricity, so the reliability of the transformer must always be considered. Transformers can

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experience problems at any time, so transformers are supported by security measures implemented according to their needs.

Transformers in electrical systems require different levels of protection. This protection is provided by various types of relays, both electromagnetic and static. In general, the purpose of transformer protection is to protect the transformer if a disturbance occurs, so that the transformer can avoid damage. The relay used to protect the transformer is a differential relay. The distance between the electricity generator and the load is very far, so a power transformer is needed to increase and decrease the voltage to minimize losses during the process of distributing electric power. During transformer operation, disturbances often occur which can hinder the operation of the transformer, therefore safety and preventive measures are needed to protect the transformer so that it can work normally considering the correct operation of the electrical system. . Electrical power protection is a form of protection for electrical equipment whose role is to prevent equipment damage and maintain the stability of electric power distribution.

The differential relay is a safety device against short circuit currents, unbalanced currents, with the principle of working as quickly as possible to overcome transformer damage. Under normal conditions, the amount of current flowing through the electrical equipment to be protected circulates in loops on both sides of the work area. If there is a fault in the operating area of the differential relay, the currents from both sides are added together, the relay commands the circuit breaker to interrupt the current, and the differential relay operates.

Literature Review

Transformer

A transformer is a tool or machine that transfers power or electrical energy from high voltage to low voltage or vice versa. Power interruptions often occur in power supplies, so protective devices are required to protect against these interferences. One of the safety systems that can be used on transformers is a differential relay. Differential relays are one of the most important protection devices for transformers operating at high speeds without coordination with other relays. Differential relays operate when the vector difference between two or more electrical quantities exceeds a predetermined quantity, differential relays also cannot be used as backup or backup protection.

A protective relay is a device setting to detect or measure Interrupt or start to notice anomalies in a device or part of an electric current system and automatically give a command to open a switch to disconnect a device or part of a system that is not functioning and provide a signal in the form of a light or bell. Communicating Protection can detect or view interference on connected devices measuring or comparing variables assigned to it, e.g. B. current, voltage, power, gain angle, frequency, impedance and so on, with predetermined sizes.

A current transformer (CT) is an electrical device that changes electric current so that it can be used for measurement purposes and as a protective relay. CTs are used to measure hundreds of amperes of current through a network, so they must be converted to match the device rating. In this case it can be seen that the primary winding of the current

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transformer is connected in series with the system, while the secondary winding is connected to the protection relay. A current transformer is needed to convert a strong current into a weak current of 1-5A, proportional to the primary current and in phase. (Firdausi et al, 2020). One of the most important transformer protection measures is the differential relay. The differential relay works without coordination with other relays, because this relay works without coordination with other relays, so the operation of this relay also requires fast time.

A static electrical device is like a power transformer, one of the functions of which is to transfer one power circuit to another circuit, either changing the voltage without having to change the frequency. This transformer consists of a coil, a mutual inductance where the primary side coil is the power receiver and the secondary side coil is connected to the load. Both coils are wrapped around a core such as laminated magnetic material.

The transformer is an important part of the substation. which functions to flow electricity from high voltage to low voltage or vice versa and is expected to work optimally because it can affect the electrical system. Because the role of the transformer in the electrical system is very important, a reliable transformer protection system is needed to protect it from disturbances that occur in the transformer (Zulkarnaini et al, 2021).

The physical basis of a transformer is the mutual inductance between two circuits required for a common magnetic flux to flow through a low resistance path. Both coils have high mutual inductance. When the coil is connected to an AC voltage source, an alternating magnetic flux is generated in the laminated core. Most of this alternating magnetic flux gets caught in another coil and induces an electromotive force.

Transformer Working Principles

In essence, the transformer works on the basis of Faraday's law of induction "an electric force through a closed curved line is directly proportional to the change in unit time of the induced current or flux circled by the curved line". Apart from the law stated in this rule, he also uses Lorentz's law of alternating electric current that flows around an iron core so that the iron core will turn into a magnet and if the magnet is surrounded by a winding then the two ends of the winding will have a voltage difference. ". In simple terms, the working method used by a transformer as its basic working principle is to follow the basic concept of mutual induction in a circuit connected by magnetic flux. A transformer consisting of 2 separate coils, separated electrically but not magnetically, the magnets are connected via an induction path. This coil has very high mutual induction If an alternating voltage is connected between a coil, from within the iron core there is an alternating flux connected to the coil which can cause an induced emf which comes from Faraday's law.

Where: e : Induced electromotive force
Ø : Number of coil turns
d /dt : Instantaneous flux change (Weber)

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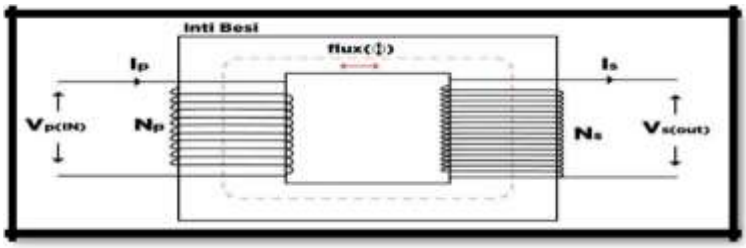

Figure 1. Principle Transformer

Electricity System

In general, the electric power system can be said to consist of three main parts, namely: electric power generation, electric power distribution, and electric power distribution. The modern electric power system is a complex system consisting of a generating center, transmission lines and distribution networks which function to distribute power from the generating center to the load center. To fulfill the operational objectives of the electric power system, the three parts, namely generation, transmission and distribution, cannot be separated from each other as shown in Figure 2.

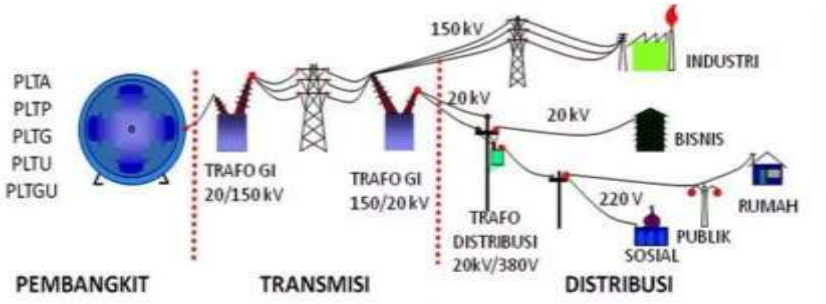

Figure 2. Electricity System

Generation is the process by which electricity is created, electricity is an energy where energy can only be changed, it can be from any energy, for example PLTA (Hydroelectric Power Plant) from water energy, PLTU (Steam Power Plant) from hot steam, PLTP (Power Plant). Geothermal). The principle of generating electrical energy is that basically the energy that will be converted into electrical energy is used to rotate the connected turbine with a generator, in the generator there are coils and magnets driven by a turbine which moves by primary energy, producing electromagnetism which will produce electricity. The electric voltage produced by the power generator is around 12 KV – 20 KV and is distributed to Transmission, before entering Transmission the voltage is increased by a Step Up Transformer.

Transmission is the process of distributing electricity from electricity generation to electricity distribution. The standard voltage in the transmission system in Indonesia is classified as extra high voltage (TET), namely with a voltage of 500 KV for high voltage distribution (TT) with a reduced voltage of 150 KV and 70 KV for distribution. However, the use of 70 KV high voltage is mostly in the East Java region, in the Central Java region it is rare to find the use of 70 KV high voltage systems. The purpose of increasing the voltage

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from generation is to minimize power losses and voltage drops, because distribution must be via a long path, the longer the path, the more it will affect power losses if the voltage is not increased. Examples of consumers who use direct supply from high voltage such as cement factories or large industries.

Distribution is the distribution process from transmission to consumers. Distribution is divided into primary distribution and secondary distribution. Primary distribution is the distribution of electricity from transmission whose voltage has been reduced by a step-down transformer to 20 KV which is classified as medium voltage (TM), and distributed through feeders. Examples of consumers using medium voltage (TM) networks are businesses such as malls, hotels and medium-sized industries. Before entering secondary distribution, the voltage will be reduced again by a step-down transformer to the use voltage. Secondary distribution is the channel from the distribution step-down transformer to the customer's kWh for households and offices. The voltage in the secondary distribution is the use voltage, namely 380/220 Volts which is classified as low voltage (TR).

In this final assignment report the author focuses more on the distribution or transmission system of electric power. The transmission system consists of transmission lines, substations, and load regulation. Transmission lines based on their installation are divided into:

1. Overhead Lines, transmission lines that transmit electrical energy through wires hung on insulators between transmission towers or poles. The weakness of this air channel is that it is hampered by the weather, the disturbances often occur due to lightning, fallen trees, kites, birds landing and many more.
2. Underground cable channels (underground cables), transmission lines that transmit electrical energy through cables buried in the ground. Usually installed in densely populated urban areas. An example of using underground cable channels is the Simpang Lima 150 KV Main Substation.

Transformer Protection System

The transformer is one of the important components in a substation that requires security so that if a disturbance occurs, the disturbance does not damage the equipment and disrupt the working system of other components. In the electricity system it is impossible to run normally, there must be interference. Of course, this disturbance cannot be eliminated, but it can be prevented with a protection system. To secure substation equipment, it is necessary to have a protection system to protect the equipment from both system and non-system interference. The definition of a protection system is a complete arrangement of protection devices consisting of the main device and other devices needed to perform certain functions based on protection principles in accordance with the definition contained in the IEC 6255-20 standard.

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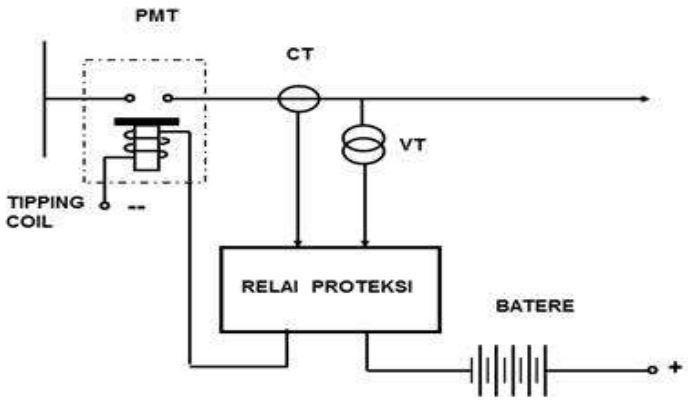

Figure 3. Protection System Device

To supply power to the protection relay and PMT so that it can process the information received and give commands to the PMT, a source is needed DC is 110V so it can carry out commands received from the safety relay. Safety relays or protection relays are equipment to detect disturbances or abnormal conditions in the electric power system, function to relieve/isolate disturbances, eliminate abnormal conditions, and to produce signals or indications. The protection relay will read the conditions provided by the instrument transformer (consisting of a current transformer and a voltage transformer), these two transformers become the input for the protection relay to read, compare and measure conditions when normal or when a disturbance occurs. When the protection relay senses a disturbance, the relay will trigger the tripping coil on the PMT to give a command to the PMT to trip.

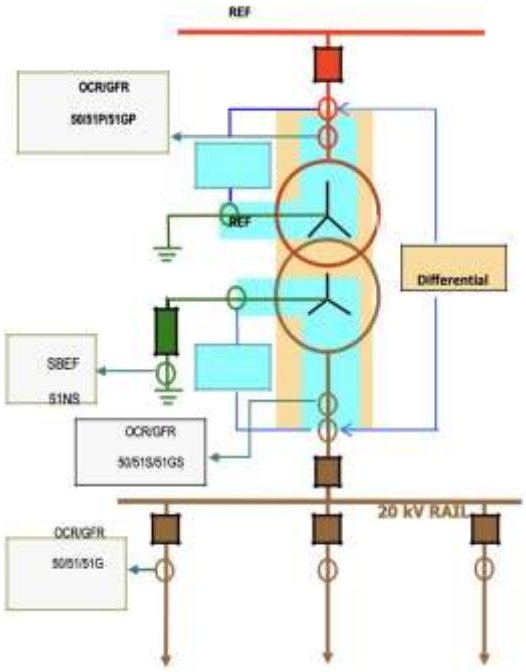

Figure 4. Transformer Electrical Protection Scheme

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The protection pattern in double busbar configuration substations is divided into main protection and backup protection. This backup protection works if the main protection fails to order a trip to the PMT and the main protection cannot carry out a trip command to the PMT outside its safety area. In the discussion of this final assignment the author will discuss the main protection on the transformer, namely the differential relay.

Differential Relays

A differential relay is a relay that comes from the word differential which is difference or difference and works according to Kirchhoff's law. That is, it works by comparing the magnitude of the input current (Ip) and the magnitude of the output current (Is) within the protected area. Differential relays are used in power transformers to protect the transformer windings in case of short circuit faults. This relay notifies the PMT to trip when an error occurs. If the transformer is damaged, the relay will function if there is a difference between the input current and the output current of the transformer. Like power transformers, differential relays function as primary protection and can protect generators, busbars and transmission lines from interference and prevent fatal damage (PT. PLN Persero, 2014).

A differential relay is a relay that works when it detects a difference in phasors and/or a difference in the instantaneous value of the incoming current and outgoing current. In this case, the comparison of primary, secondary and/or tertiary winding currents (if the tertiary is loaded). The working principle of a differential relay is to compare two or more current vectors entering the relay.

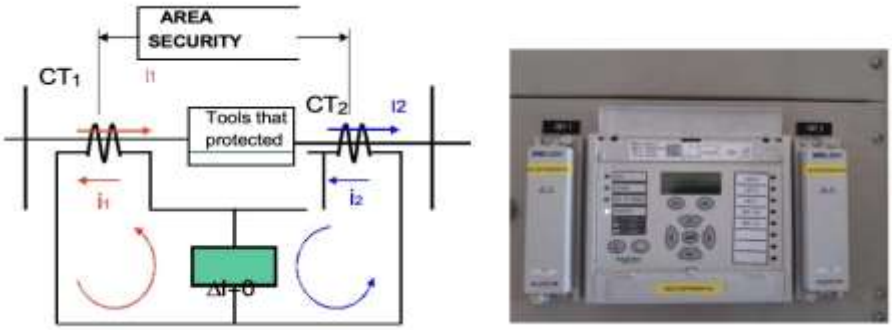

Figure 5. Differential Relay Circuit and physical image of the relay

METHOD

The main protection for the 150 kV High Voltage Air Line has a very important role, considering that there is a SUTT for consumers at the PLN Main Substation which supplies quite a large amount of power for PT's High Level Consumers (KTT). Holcim, so there needs to be quite intense monitoring to maintain the electricity supply reaching consumers. Current existing conditions at relay using a Distance Relay, in terms of hardware the capability of this equipment is of course still good, but functionally there are several things that are taken into consideration when replacing the distance relay, namely:

a. The distance between one GI and the adjacent opposing GI b. There was a case of malemployment
b. Reliability of the protection system

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The main protection on transmission lines has factors that can influence it. One of the influencing factors is the length of the transmission line which is based on the comparison of the source impedance to the impedance of the line being protected. This term can be called source impedance ratio (SIR). SIR shows the strength of the system to be protected, the smaller the SIR, the stronger the source supplying the transmission line. The simpler SIR grouping is as follows:

Table 1 Source Impedance Ratio

CHANNEL LENGTH	SIR
Short Channel	SIR≥4
Medium Channel	0.5ohm ≥ SIR ≥ 4
Long Channel	SIR ≤ 0.5

Currently the relay installed in the Cibinong 2 direction at the Semenbaru substation uses a distance relay with the GE Multilin/D60 relay type.

$$Zs_{3PH} = \frac{V_{drop}}{I_{relay}} = \frac{V_{base\ L-N} - V_{relay}}{I_{relay}}$$

$$Z1_L = Z_{kabel}\ x\ Z_{saluran}$$

$$SIR = \frac{Zs_{3PH}}{Z1_L}$$

RESULT

Analysed.

However, the distance between sei rotan and perbaungan is less than 10 km. On short lines, it is not recommended to use distance relays, because the distance is too close. As well as the many disturbances that occur on the sei rotan – perbaungan high voltage overhead lines.

Table 2. Disorder History Table

Bay name	Date Incident	O'clock Go out	Relay Yang Work	Condition
GI CBNG BAY PHT 150 KV SMNBRU	16-20-2018	23.26	Three poles discrepancy	Trip Permanent
GI CBNG BAY PHT 150 KV SMNBRU	04-21-2010	10.02	Nothing is Work	Trip Permanent
GI CBNG BAY PHT 150 KV SMNBRU	04-21-2010	20.35	Nothing is Work	Trip Permanent
GI CBNG BAY PHT 150 KV SMNBRU	12-19-2012	11.01	Bagno A Z1, Z2, Z3 (False Protection)	Trip malemployment Relays bagno B90
GI SMNBRU BAY PHT 150 KV CBNG	01-03-2017	15.10	Distance relay Zone 1	Reclose Success
GI CBNG BAY PHT 150 KV SMNBRU	01-03-2017	15.10	Distance relay Zone 1	Final Trip
GI SMNBRU BAY PHT 150 KV CBNG	05-05-2017	20.15	Distance relay Zone 3 (Protection Wrong)	Trip

Based on table 2 above, the disturbances that have occurred at UPT Medan, Traagi can be seen In fact, the Cibinong - Semenbaru conductor often experiences interference.

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Even in April 2010 there were indications that none of the relays were working. It can also be seen in table 2 that in May 2017 there appeared to be interference with the relay that was working, namely distance relay zone 3. This can be said to mean that the relay was working less selectively and reliably. Another thing that can be said to be less selective is that distance relays have low resistance to disturbance. Where when a disturbance occurs, the distance sometimes shows the location of the disturbance incorrectly. This makes recovery take longer and the savings value becomes lower

Calculations and Analysis

Calculations Before Replacing Distance Relays

The results of research on the Cibinong Semenbaru transmission system are impedance values in zone 1, zone 2 and zone 3. The data used in this research was obtained from UPT Sei rotan, namely:

a. CT and PT ratio data
   CT = 1000:1
   PT = 150,000:100
b. Length of GI transmission line conductor Sei rotan – Perbaungan = 42.11 km

The impedance value for the length of the transmission system line can be calculated using equations 2.2, 2.3, 2.4 and 2.5 as follows: Impedance of the Sei rotan GI – Perbaungan GI line:

ZL1 = 4.11 x (1.3178 + J 0.5762) Ω ZL1 = 1.30615 + J 2.3677 Ω

Zone 1

Z1 = 0.8 X (3.14744 + J 2.3677) Ω
Z1 = 1.0880 + J 1.8941 Ω
With zone1 protection range is 0.8 x 4.11 = 3.2 km
The zone uses instant working time because as the main security t = 0 s.

Zone 2

Z2 = 0.8 ((1.306 + J 2.3667) + (0.8 X (3.8167 + J 6.9168)
Z2 = 0.8 (4.551 + J 7.9018)
Z2 = 3.6114 + J 7.2144 Ω
With zone 2 protection coverage is
= 0.8 (4.11+ (0.8 x 12.01))
= 12.89 km
The working time in zone 2 is longer than zone 1, namely t = 0.4 s

Zone 3

Z3 = 1.6 ((1.306 + J 2.3677) + (3.8167 + J 6.9189)
Z3 = 8.1957 + 14.957Ω
With zone 3 protection coverage is
= 1.6 (4.11+12.01)
= 25,792 km

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The working time in zone 3 takes into account the longer protection length of zone 1 and zone 2, then the setting time for zone 3 is t = 1.6 s. The impedance value that can be seen by the relay is obtained from the following equation:

CT ratio = 1000:1 A
PT ratio = 150,000 : 100 V
Z = (CT / PT) x Zone CT Ratio = 1000:1 A PT Ratio = 150,000 :
100 V n = (100 /150000) / (1/1000) n = 0.66

Calculations in zone 1 seen by the relay:

= 0.66 (1.0880 + J 1.8941)
= 0.7180+ J 1.2501 Ω

Calculations in zone 2 seen by the relay:

= 0.66 (3.6110 + J 7.214)
= 2.376 + J 4.7612 Ω

Calculations in zone 3 seen by the relay:

= 0.66 (15.671 +J 27.625)
= 10.342 + J 18.232 Ω

Impedance Value

The impedance value obtained from the Sei rotan- Perbaungan conductor calculation is 0.7180 + J 1.2501 Ω, the ability of distance relay to protect the transmission system is very good because the distance between transmission systems is usually very far between substations. However, if the distance relay is not too far, the impedance read on the distance relay is very small (between 0.71 – 4.7 ohms) which is why at a distance that is not too far, it is usually under 10 km. It is feared that distance relays will not be selective in reading interference.

Table 3. Calculations After Replacing Line Current Differential

Line Length (Ln)	: 4.1km
Nominal Voltage (KV)	: 150000
CT Ratio (CT)	: 2000/1 A
CT Remote Ratio (CTr)	: 1600/1 A
PT Ratio (PT)	: 150000/100 V
Frequency (F)	: 50 Hz
Line Impedance	
Line Resistance (R1)	: 0.0662 Ω/km
Line Reactance (X1)	: 0.2807 Ω/km

Conditions: Ic < I diff < If min Calculating the Ic Value (Charging Current)

Ic = KV / (√(3 x Xc)
Bt = B x Ln
Bt = (4.023 x 10 x 0.000001) x 4.1 Bt = 1.6 x 10 x 0.00001

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Xc = 1 / (Bt) = 1/ (1.6 x 10 x 0.00001)
IC = ((150 x 1000) / (√(3 x1.6 x 10 x 0.00001)
Ic = 1.38n Amperes
Ics = ICT / CT = 1.38 / 2000 = 6.9 x 0.0001

Relay linecurrent differential

Install it on the Sei rotan- Perbaungan overhead line conductor rather than distance relay, because this relay has no effect on impedance, it only calculates the current at the substation in front of it. However, the problem is that the cost is more expensive than installing a distance relay. Because the line current differential requires fiber optics. The longer the fiber optic installed, the greater the costs accumulated for installing the fiber optic in the system. *Benefits*is the convenience or other benefits that result. Benefits that can be obtained after replacing the relay on the conductor include:

a. The potential for load outages due to disturbances in the conductor is decreasing
b. Speeds up the time to find the cause of the problem.
c. Increased consumer confidence due to increasingly improving reliability of the electric power system.

CONCLUSION

From the results of the calculations and analysis in the following conclusions can be drawn: The Source Impedance Ratio (SIR) obtained on the Sei rotan–perbaungan conductor is 6.383. According to SPLN T5.002-1.2010, for short conductors, if the SIR result is greater than <4, selectivity is difficult to achieve when using an impedance type relay, so as a solution, a differential type relay is chosen, so it can be said to be a short conductor and for the protection system it is better to use a Line Current Differential relay. Calculating the impedance of the distance relay on the Sei rotan – perbaungan high voltage overhead line, the results were very small, 0.7180+ J 1.2501 Ω, it was feared that the relay would not be selective in reading disturbances.

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