BirEx JOURNAL
Budapest International Research in Exact Sciences
Medical, Biological, Argriculture, Engineering Science and other related areas
e-ISSN : 2655-7827
p-ISSN : 2655-7835
http://www.bircu-journal.com/index.php/birex

Study on the Use of CT Ring Protection as Back up Protection for Overcurrent Disruptions in PLN Distribution Network System

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Abstract: *Protection is a safeguard in the electric power system installed in the electric power distribution system, power transformers, electric power transmission, and electric generators used to protect the electric power system from electrical disturbances or overloads by separating the disturbed part of the electric power system from the existing electric power system. Not disturbed so that the uninterrupted electrical system can continue to work. Failure of the protection system at the KG02 and KG 180 substations at PT PLN (Persero) UP3 Tanjung Priok when short circuit currents occurred on the phases on the consumer side resulted in the PMT (Power Breaker) of the feeder tripping. This resulted in widespread outages which had a negative impact on the image of PT PLN (Persero) UP3 Tanjung regarding network reliability. To find out the cause of the protection system failure, CT (Current Transformer) checks were carried out on the three substations. At the KG02 substation, the 345KVA CT power contract is installed with a ratio of 10/5 and class 5P10 with a fault current of 2861A. At the KG180 substation, the CT is installed with a ratio of 100/5 with class 5P10 with a fault current of 6547A. . From the results of the data from the two substations above, the protection system failure occurred in the current transformer which was saturated when a fault current exceeded 2861A and 6547A. To overcome protection failures at the two substations above, it is necessary to add a CT Ring 800/5 with class 5P20, with the test results being a reference for improving the protection system so that similar failures do not happen again.*
Keywords: *Protection system; short circuit; CT Ring*

I. Introduction

The protection system plays a very important role in the reliability of an electrical network in order to prevent/isolate electrical network points that are disturbed due to overcurrent or overload, which can result in widespread power outages and can even damage the electrical equipment if the protection system fails. The protection system consists of several components such as: Power supply, circuit breaker (breaker switch, PMT), relay, current transformer, voltage transformer (potential transformer).

Protection reliability plays an important role in increasing network reliability and the performance of each Customer Service Implementation Unit (UP3) at PT PLN (Persero). On the performance side, protection reliability is one way to reduce the FGTM index value. Interference in the distribution of medium voltage electric power in a certain period that occurs every 100 circuit kilometers (km) of network length can be notated as a disturbance index per 100 km, known as Medium Voltage Frequency Interference (FGTM). With a total SKTM cable asset length of 709.70 km, the performance value of FGTM UP3 Tanjung Priok in 2020 is 10.7.

DOI: https://doi.org/10.33258/birex.v6i1.7810

Table 1.FGTM UP3 Tanjung Priok

No	Reason	Feeder Trip 2019	Feeder Trip 2020	Percentage of 2019	Percentage of 2020
1	SKTM	11	2	28%	3%
2	Jointing	12	21	30%	36%
3	Missing	10	9	25%	16%
4	SKTM GTJ	0	1	0%	2%
5	Sympathetic	0	0	0%	0%
6	Indoor	2	2	5%	3%
7	Med-Voltage Cell	2	6	5%	10%
8	Transformer	0	0	0%	0%
9	MVCell busbars	0	0	0%	0%
10	Current Transformer	0	0	0%	0%
11	Voltage Transformer	0	0	0%	0%
12	TM Fuse Disconnected	0	3	0%	5%
13	Corona	0	0	0%	0%
14	Animal	1	3	3%	5%
15	Customer	2	7	5%	12%
16	SCTM	0	1	0%	2%
17	MVCell blade	0	0	0%	0%
18	Kite	0	2	0%	3%
19	Tree	0	1	0%	2%
	Total	**40**	**58**	**100%**	**100%**

In Table 1, one of the highest contributors to UP3 Tanjung Priok disruption in 2020 was Customer Installation Disruption which reached 12%. This is due to a failure in the protection system towards the customer's special substation when a disturbance occurs in the consumer's installation, which causes the Feeder Power Breaker (PMT) to trip. One of the feeders that tripped due to protection failures at the consumer's special substation in 2020 was the Kaktus feeder, where the Kaktus feeder tripped twice with MOC relay indications in the same year at the KG 02 and KG180 substations which are customers of the Special Substation owned by PT PLN (Persero) UP3 Tanjung Priok, KG02 supplies electricity to customers with a contract power of 345 KVA, namely STO Telkom Kelapa Gading and KG180 supplies electricity to customers with a contract power of 3,805 KVA, namely PT Lotte Shipping Kelapa Gading.

The protection contained in the KG02 and KG180 substations functions to protect interference originating from the customer's installation side. However, on July 8, 2021, and November 23, 2020, disturbances arising from customer installations did not activate protection at substations KG02 and KG180 properly, causing the PMT (Power Breaker) of the Kaktus Feeder to trip twice in 2020. This resulted in blackouts throughout the year. The Cactus Feeder that shouldn't have happened. The incident experienced by the KG02 and KG180 Kaktus Feeder substations is the object of this research.

FREKUENSI GANGGUAN TEGANGAN MENENGAH (FGTM) UP3 TANJUNG PRIOK 2020

GANGGUAN PENYULANG

GARDU INDUK	PENYULANG	TITIK GANGGUAN	AMPERE	INDIKASI RELAY	TGL PADAM	JAM PADAM	TGL NYALA	JAM NYALA	LAMA PADAM	PENYEBAB GANGGUAN
KELAPA GADING	KAKTUS	KG180	50	MOC	23 November 2020	16:11:00	23 November 2020	16:35:00	0:24:00	IB KONSUMEN
KELAPA GADING	KAKTUS (CBO)	KG 02	50	MOC	08 Juli 2020	8:19:00	08 Juli 2020	8:32:00	0:13:00	IB KONSUMEN

Figure 1. *FGTM in 2022 due to Consumer IB*

From the FGTM above, the indication of the relay fault current from the KG 02 and KG180 substations is MOC, the settings on the feeder for MOC are 4000A, while KG02 is installed with CT 3 x 10/5A with class 5P10 and KG180 is installed with CT 3 x 100/5A with class 5P10. From a technical perspective, the indication of protection failure at the KG02 and KG180 substations is due to the small CT value and small class, which can disrupt the reliability of the protection system. From the network reliability perspective, widespread outages reduce the reliability of PT's distribution network. PLN (Persero). Meanwhile, from an economic perspective, this is detrimental to PT. PLN (Persero) because it cannot sell electrical energy in areas that do not experience disruption (Energy Not Serve). Apart from that, widespread blackouts also create a bad image in the eyes of the public.

Therefore, the author chose the title "Study on the Use of CT Ring Protection as back-up protection for overcurrent in the PLN distribution network system" in order to anticipate protection failures and maintain the reliability of the protection system. It is hoped that there will beIn this analysis, similar incidents can be avoided so as to reduce potential losses and increase the reliability of PT PLN (Persero) UP3 Tanjung Priok.

II. Review of Literature

2.1 Medium Voltage Electric Power Systems

The electric power system consists of several electric power components such as power plants, transmission systems, and distribution systems. These three components are the core of an electric power circuit which works to distribute electrical power from the generating center to the load centers(Widyastuti et al., 2021). The electric power system can be seen in Figure 2.

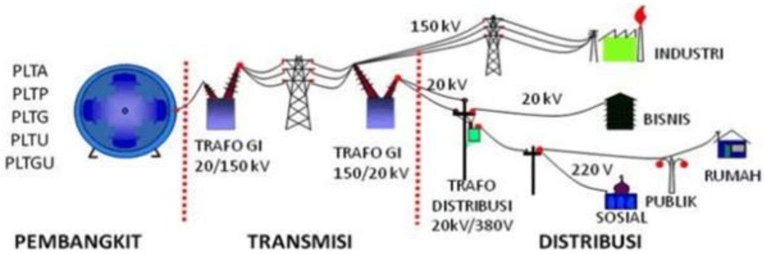

***Figure 2**. Electric Power Systems*
(Widyastuti et al., 2021)

Energy from the generating center is channeled through transmission lines then through distribution cable lines and reaches consumers. The following is an explanation of the main parts of the electric power system, including:

Electricity Generating Center (Power Plant) The power generation center is the beginning of electrical energy being generated. In the generator itself there is a turbine as the initial mover (PrimeMover) and a generator which generates electricity by converting turbine power into electrical energy. Usually at the power plant center there is a main substation. The substation consists of several main equipment, including transformers, which function to increase and decrease the voltage.

Electric Power Transmission In electric power transmission, there is a process of distributing electric power from the electricity generation center to the electricity distribution channel so that it can be distributed to electricity users. In electric power transmission, the voltage from generation is increased to the standard Indonesian transmission voltage, namely 70kV, 150kV and 500kV.

Distribution System The distribution system is an electric power sub-system that is directly connected to electricity users and generally functions in terms of distributing electric power to several places. The distribution system itself consists of several sub-systems consisting of a control center or main substation, switch substation, medium voltage lines or primary networks (6kV and 20kV) in the form of overhead lines or underground cables, low voltage lines or secondary networks (380V and 220V), voltage distribution substation consisting of voltage control panels, both medium voltage and low voltage, and transformers.

2.2 Disturbance

A disturbance is a situation where there is a failure in the electric power system which results in disruption of the normal flow so that the current flowing in the three-phase system becomes unbalanced. Disorders can be grouped into several groups, namely:

a. Asymmetric disorders

This disturbance is a disturbance that causes an imbalance in the voltage and current flowing in each phase. This disturbance consists of: Single Phase Short Circuit to Ground Fault. This disturbance is a disturbance that occurs because one of the phases is briefly connected to the ground. Two Phase Short Circuit Fault. This disturbance is a disturbance that occurs because the phases between the two phases are briefly connected to each other and are not connected to the ground. Two-Phase Short Circuit to Ground. This disturbance is a disturbance that occurs due to the presence of two phases that are briefly connected to the ground.

b. Symmetrical disorder

This disturbance is a disturbance that occurs in all phases, which causes both the current and voltage in each phase to remain balanced when a disturbance occurs.[9] The types of disturbances included in symmetric disturbances are: Three Phase Short Circuit Fault. This disturbance will appear when each phase is briefly connected to each other.
Three Phase Short Circuit to Ground. This disturbance is a disturbance caused by the short connection of the three phases to the ground.

The most common type of fault is single-phase ground fault with a percentage of 70%. This type of disturbance occurs when one of the phases of the line is connected to the ground, either due to snow, wind, or fallen trees. (IDGAB Udiana, IGD Arjana, and GI Partha, 2017).

2.3 Symmetric Component Method

Disturbances that occur in electric power systems are generally asymmetrical disturbances, where the disturbance causes the voltage and current flowing in each phase to become unbalanced. In 1918, CL Fortesque discovered a method that can be used to analyze unbalanced three-phase systems [1]. Fortesque proved that an unbalanced system consisting of unbalanced voltages or currents between phases can be broken down into three symmetric components of a balanced three-phase system.

2.4 Short Circuit Fault

In electric power system protection, it is very important to know the distribution of current and voltage in various places as a result of disturbances. The working characteristics of protective relays are influenced by the amount of energy monitored by the relay, such as current or voltage. By knowing the distribution of current and voltage in various places, a protection engineer can determine the settings for the protection relays and the rating of the circuit breaker (CB) that will be used.

III. Research Method

The Root Cause Analysis research method begins by taking data in the form of specifications for the type of Medium Voltage customer power contract at PT PLN (Persero) UP3 Tanjung Priok and data on distribution substations in the form of specifications for Current Transformers, Voltage Transformers, TVS, Relay Types, coordination of protection relay settings and data SKTM. The data on the substation obtained is in the form of power transformer specifications, protection relay settings and short circuit current. Then, testing, calculation and analysis steps are carried out on various factors that cause protection system failure, including:

a. The criteria for Medium Voltage Customer power contracts at PT PLN (Persero) UP3 Tanjung Priok vary, so the CT that is installed for protection also adjusts the CT for measuring meters/power limiters for medium voltage consumers so this can be a problem for protection failure if a CT Ring is not installed. passed by overcurrent current.
b. Coordination of protective relay settings is very important for the reliability of the protection system. Coordination of protective relay settings is the way protection relays work in distribution substations with protection relays in PMT feeders at main substations so that current or time setting values do not collide in the same network. The 20 KV protection relay is set based on the time-grading principle, where the trip time is based on the duration of the fault current level that occurs.
c. Reliability of the protection system is a part that must maintain the quality of each component. If one of the components is unreliable/damaged, the protection system will not work reliably and can cause failure of the protection system. Meanwhile, the selection of protection device specifications must be in accordance with the network requirements for electricity that we will secure.

IV. Results and Discussion

The Moment Over Current short circuit fault that occurred at the KG02 substation and KG180 substation on the consumer side caused a trip on the Kaktus feederwhereasCircuit Breaker Outgoingsubstations KG02 and KG180 do not trip. During a Moment Over Current short circuit at the KG02 substation on the Kaktus feeder, the current magnitude is 9730 A, whereas when the Moment Over Current short circuit occurs at the KG180 substation on the Kaktus feeder, the current magnitude is 9730 A. Protection failure at substations KG02 and KG180on the consumer side which causes the Kaktus feeder to trip cause lossesEnergy Not Serve(ENS) for PT PLN (Persero) UP3 Tanjung Priok because there is KWH that is not distributed to other substations at the cactus feeder due to the Outgoing Circuit Breakersubstations KG02 and KG180 do not trip or work.

4.1 Calculation of Energy Not Served (ENS)

a. ENS Substation KG02 Cactus Feeder

Based on the report from the Distribution Command Center (DCC) UP2D Jakarta Raya, when there was a disruption to the cactus feeder at the KG02 substation due to Moment Over Current short circuit disturbance On the consumer side, the load on the Kaktus feeder when tripping is 50 A, while the time for investigating disturbances in the acceleration of ignition of all substations or the recovery time for the Kaktus feeder is 13 minutes (0.216 hours). Using the rupiah price per KWH of 1,444.70. So, the amount of energy that is not distributed during the disturbance is:

Power (P) = $V_{p-p} \times I \times \sqrt{3} \times Cos\,\theta$

ENS =$V_{p-p}(kV) \times I_{beban}(A) \times \sqrt{3} \times Cos\,\theta \times T_{padam}(jam) \times \frac{Rp}{KWH}$

=$20\ kV \times 50\ A \times 1{,}73\ \times 1 \times\ 0{,}216\ jam \times 1.444{,}70\ \frac{Rp}{KWH}$

= 539,855 rupiah

b. ENS KG180 Cactus Feeder Substation

Based on the report from the Distribution Command Center (DCC) UP2D Jakarta Raya, when there was a disruption to the cactus feeder at the KG180 substation due to Moment Over Current short circuit disturbance On the consumer side, the load on the Kaktus feeder when tripping is 50 A, while the time for investigating disturbances in the acceleration of ignition of all substations or the recovery time for the Kaktus feeder is 24 minutes (0.4 hours). Using the rupiah price per KWH of 1,444.70. So, the amount of energy that is not distributed during the disturbance is:

Power (P) = $V_{p-p} \times I \times \sqrt{3} \times Cos\,\theta$

ENS =$V_{p-p}(kV) \times I_{beban}(A) \times \sqrt{3} \times Cos\,\theta \times T_{padam}(jam) \times \frac{Rp}{KWH}$

ENS =$20\ kV \times 50\ A \times 1{,}73\ \times 1 \times\ 0{,}4\ jam \times 1.444{,}70\ \frac{Rp}{KWH}$

ENS= 999,732 rupiah

4.2 Short Circuit Current Calculation

a. Short Circuit Current CalculationGI Kelapa Gading

The following is the technical data on the power transformer and short circuit current of GI Kelapa Gading which is needed to calculate the source reactance and transformer reactance:

Table 2. Kelapa Gading GI Technical Data

No	Technical Data	Information
1	Brand	B&D
2	Serial No	PX-070FOMB
3	Standard	IEC 60076
4	Capacity	60 MVA
5	Primary Voltage	150 kV

6	Secondary Voltage	20 kV
7	Transformer Impedance	12.08%
8	Connection	YNyn0 + d
9	NGR (R_N)	12 Ω
10	Short Circuit Current	28.13 kA

b. Source ReactanceGI Kelapa Gading

To calculate the reactance magnitude of the source located on the 20 kV side of the Kelapa Gading GI. Calculated using the following equation with technical data:

XS secondary = .$\frac{\text{kV sekunder}^2}{MVA}$

Secondary XS = = = 0.0948$\frac{20000^2}{28.130 \times 150000}$Ω

c. Transformer Reactance CalculationKelapa Gading GI Staff

To calculate the reactance of the Kelapa Gading GI Power Transformer calculated using the following equation with technical data:

Xt (at 100%) =$\frac{\text{kV}^2}{\text{MVA (trafo)}}$

Xt (at 100%) = 6.67$\frac{20^2}{60}$ =Ω

Positive and negative sequence reactance values (= power transformer using the equation vizX_{t1} X_{t2})

X_{t1}= % x (at 100%) = 12% x 6.67 Ω = 0.8 Ω$X_t$$X_t$

The value of the zero sequence reactance () of the power transformer (taking into account the delta winding capacity) uses the equation, namelyX_{t0}

X_{t0}= x 0.8 Ω = 2.4 Ω3X_{t1} = 3

d. Calculation of Short Circuit Current for KG02 Substation Feeder

1. Impedance CalculationFeeder Katus Substation KG02

The Kaktus Feeder has 8 distribution substations connected to GH 19 with a JTM length of 3865m using NA2XSEKBY 240 aluminum conductors with conductor impedances of 0.125 Ω/km and 0.31 mH/km (IEC.502). The KG02 substation is the 8th substation out of a total of 8 Kaktus feeder substations with a cable length of 3445 meters using NA2XSEKBY 240 aluminum conductors, while the cable length from the KG02 substation output to the TM customer installation/fault point is 20 meters using NA2XSEKBY 240 aluminum conductors.$mm^2$$mm^2$$mm^2$

Table 3. Impedance of Ground Cables with IEC.502 standard Al Conductors

A (mm^2)	R (Ω/km)	L (mH/km)	C (mf/km)	Impedansi urutan positif (Ω /km)	Impedansi urutan Nol (Ω/km)
150	0,206	0,33	0,26	0,206 + j 0,104	0,356 + j 0,312
240	0,125	0,31	0,31	0,125 + j0,097	0,275 +j0,029
300	0,100	0,30	0,34	0,100 + j0,094	0,250 + j0,282

a. GI impedance of P. cactus – GH119 (NA2XSEKBY 240 3,865 km long)mm^2
v (0.483 + j 0.375) ΩZ_{1G}
= (1.063 + j 0.112) Ω Z_{0G}
b. GI impedance of P. cactus – KG02 (NA2XSEKBY 240 3,445 km long)mm^2
= (0.431 + j 0.334) ΩZ_{1P}
= (0.947 + j 0.100) Ω Z_{0P}
c. Impedance KG02 – Customer Installation (NA2XSEKBY 240 0.02 km long)mm^2
= (0.003+ j 0.002) ΩZ_{1K}
Z_{0K}= (0.006 + j 0.001) Ω

2. Network Equivalent Impedance CalculationFeeder Katus Substation KG02

The calculation of the network equivalent impedance is the calculation of the positive (eq) and negative (eq) impedance values from the point of disturbance to the source. Calculated using Eq$Z_1 Z_2$
Z_1eq = eq = + + +$Z_2 Zs_1 Zt_1 Z_{1P} Z_{1K}$
= (0 + j 0.0948) + (0 + j 0.8) + (0.431 + j 0.334) + (0.003 + j 0.002) =
= (0,434 + j 1.239) Ω
The value of zero sequence impedance (eq) can be calculated using the following equationZ_0
Z_0eq = + 3 + +$Z_{t\ 0} R_N Z_{0P} Z_{0K}$
= (0 + j2,4) + (3×12) +(0.947 + j 0.100) + (0.006 + j 0.001) =
= 36.953 + j2.501 Ω

3. Calculation of 3 Phase Short Circuit Fault CurrentFeeder Katus Substation KG02

The 3-phase short circuit fault current that has the potential to occur at the Kelapa Gading GI, from the Kaktus Feeder conductor to the outgoing KG02 Distribution Substation to the incoming customer side is calculated using the following equation:

IHS 3 phase $= \frac{V_{ph}}{z_{1\ eq}}$

$= \frac{V_{ph}}{(zs_1 + zt_1 + z_{1P} + z_{1K})}$

$= \frac{11870}{(0{,}434 + j\,1{,}239)}$

= 7.133 A

4. Calculation of 2 Phase Short Circuit Fault CurrentFeeder Katus Substation KG02

The 2-phase short circuit fault current that has the potential to occur at the Kelapa Gading GI, from the Kaktus Feeder conductors to the outgoing KG02 Distribution Substation to the incoming customer side is calculated using the following equation:

IHS 2 phase = ($\frac{V_{ph-ph}}{z_{1\,eq} + z_{2\,eq}}$ Z_1eq = eq)Z_2

$=\frac{V_{ph-ph}}{2\times(Zs_1 + Zt_1 + Z_{1P} + Z_{1K})}$

$=\frac{20000}{2\times(0{,}434 + j\,1{,}239)}$

= 6,010 A

5. Calculation of 1 Phase Short Circuit Fault CurrentKG02 Substation Feeder Phase

The 1-phase - ground short circuit fault current that has the potential to occur at the Kelapa Gading GI, on the Kaktus Feeder conductor to the outgoing KG02 Distribution Substation to the incoming customer side is calculated using the following equation:

Ihs 1 phase =$\frac{3\times V_{ph}}{z_{1\,eq} + z_{2\,eq} + z_{0\,eq}}$ (Z_1eq = eq)Z_2

$=\frac{3\times 11870}{(2\times(0{,}434 + j\,1{,}239)) + (36{,}953 + j2{,}501)}$

= 844A

e. Calculation of Short Circuit Current for KG Substation Feeder180

1. Impedance CalculationKG180 Substation Katus Feeder

The Kaktus Feeder has 8 distribution substations connected to GH 19 with a JTM length of 3865m using NA2XSEKBY 240 aluminum conductors with conductor impedances of 0.125 Ω/km and 0.31 mH/km (IEC.502). The KG180 substation is the 4th substation out of a total of 8 Kaktus feeder substations with a cable length of 1410 meters using NA2XSEKBY 240 aluminum conductors, while the cable length from the KG02 substation output to the TM customer installation / fault point is 35 meters using NA2XSEKBY 240 aluminum conductors.$mm^2mm^2mm^2$

a. GI impedance of P. cactus – GH119 (NA2XSEKBY 240 3,865 km long)mm^2

v (0.483 + j 0.375) ΩZ_{1G}

= (1.063 + j 0.112) Ω Z_{0G}

. b. GI impedance of P. cactus – KG180 (NA2XSEKBY 240 1,410 km)mm^2

= (0.176 + j 0.137) ΩZ_{1P}

= (0.388 + j 0.041) Ω Z_{0P}

c.. Impedance KG180 – Customer Installation (NA2XSEKBY 240 0.035 km long)mm^2

= (0.004+ j 0.003) ΩZ_{1K}

Z_{0K}= (0.010 + j 0.001) Ω

2. Network Equivalent Impedance CalculationKG180 Substation Katus Feeder

The calculation of the network equivalent impedance is the calculation of the positive (eq) and negative (eq) impedance values from the point of disturbance to the source. Calculated using EqZ_1Z_2

Z_1eq = eq = + + +$Z_2Zs_1Zt_1Z_{1P}Z_{1K}$

= (0 + j 0.0948) + (0 + j 0.8) + (0.176 + j 0.137) + (0.004 +7 j 0.003) =

= (0,180 + j 1.0350) Ω

The value of zero sequence impedance (eq) can be calculated using the following equationZ_0

Z_0eq = + 3 + +$Z_{t\ 0} R_N Z_{0P} Z_{0K}$

= (0 + j2,4) + (3×12) +(0.388 + j 0.041 + (0.010 + j 0.001) =

= 36.282 + j2.442 Ω

3. Calculation of 3 Phase Short Circuit Fault CurrentKG180 Substation Katus Feeder

The 3-phase short circuit fault current that has the potential to occur at the Kelapa Gading GI, from the Kaktus Feeder conductor to the outgoing KG180 Distribution Substation to the incoming customer side is calculated using the following equation:

IHS 3 phase $= \frac{V_{ph}}{z_{1\ eq}}$

$= \frac{V_{ph}}{(Zs_1 + Zt_1 + Z_{1P} + Z_{1K})}$

$= \frac{11870}{(0{,}180 + j\ 1{,}0350)}$

= 9.764 A

4. Calculation of 2 Phase Short Circuit Fault CurrentKG180 Substation Katus Feeder

The 2-phase short circuit fault current that has the potential to occur at the Kelapa Gading GI, from the Kaktus Feeder conductor to the outgoing KG180 Distribution Substation to the incoming customer side is calculated using the following equation:

IHS 2 phase = ($\frac{V_{ph-ph}}{z_{1\ eq} + z_{2\ eq}}$ Z_1eq = eq)Z_2

$= \frac{V_{ph-ph}}{2 \times (Zs_1 + Zt_1 + Z_{1P} + Z_{1K})}$

$= \frac{20000}{2 \times (0{,}180 + j\ 1{,}0350)}$

= 8.226 A

5. Calculation of 1 Phase Short Circuit Fault CurrentKG180 Substation Catus Feeder Phase

The 1-phase - ground short circuit fault current that has the potential to occur at the Kelapa Gading GI, on the Kaktus Feeder conductor to the outgoing KG180 Distribution Substation to the incoming customer side is calculated using the following equation:

Ihs 1 phase $= \frac{3 \times V_{ph}}{z_{1\ eq} + z_{2\ eq} + z_{0\ eq}}$ (Z_1eq = eq)Z_2

$= \frac{3 \times 11870}{(2 \times (0{,}180 + j\ 1{,}0350)) + (36{,}282 + j2{,}442)}$

= 865 A

4.3 Ratio Testing Analysis*Current Transformers* (CT)

Table 4. CT Protection Ratio Error Limits accIEC 60044-1 standard

Accuracy Class	+/- % CT Ratio Error
5Ps	±1
10P	±3

According to the IEC 60044-1 standard, the error tolerance limit for class 5P Protection CT is ±1% while for class 10P it is ±3%, if the Protection CT exceeds the error limit set by the IEC 60044-1 standard then there is a fault/damage to the Protection CT. The equation for the CT ratio error (current error) is as follows:

$$\varepsilon(\%) = \frac{(K_{n.}I_s) - I_p}{I_P} \text{x } 100\%$$

a. Ratio Testing Analysis*Current Transformers* (CT) KG02 Protection

Table 5. Accuracy of Substation Protection CTKG02

No	Primary (A)	Secondary (A)			Accuracy (%)			Error (%)		
		R phase	S phase	T phase	R phase	S phase	T phase	R phase	S phase	T phase
1	2	0.99	1	0.99	99	100	99	1	0	1
2	4	1.99	1.99	1.98	100	100	99	1	1	1
3	6	2.98	3	2.97	99	100	99	1	0	1
4	8	3.95	3.95	3.97	99	99	99	1	1	1
5	10	4.96	4.98	4.97	99	100	99	1	0	1

The Protection CT installed at Substation KG 02 is a class 5P10 Protection CT with a ratio of 10/5A, according to the IEC 60044-1 standard the error tolerance limit for class 5P Protection CT is ±1%. The analysis results of the 10/5A Protection CT ratio test with class 5P10 show that the Protection CT has an accuracy of above 99 percent, so it can be concluded that the Protection CT is in good condition and does not experience errors above 1% when it is supplied with current according to its nominal current.

b. Ratio Testing Analysis*Current Transformers* (CT) KG180 Protection

Table 6. Accuracy of Substation Protection CTKG180

No	Primary (A)	Secondary (A)			Accuracy (%)			Error (%)		
		R phase	S phase	T phase	R phase	S phase	T phase	R phase	S phase	T phase
1	20	0.99	0.99	1	99	99	100	1	1	0
2	40	1.98	1.99	2	99	100	100	1	1	0
3	60	2.97	2.97	2.99	99	99	100	1	1	0
4	80	3.97	3.98	3.99	99	100	100	1	1	0
5	100	4.98	4.99	4.99	100	100	100	0	0	0

The Protection CT installed at substation KG 180 is a class 5P10 Protection CT with a ratio of 100/5A, according to IEC 60044-1 standard the error tolerance limit for class 5P Protection CT is ±1%. The analysis results of the 100/5A Protection CT ratio test with class 5P10 show that the Protection CT has an accuracy of above 99 percent, so it can be concluded that the Protection CT is in good condition and does not experience errors above 1% when it is supplied with current according to its nominal current.

c. Ratio Testing Analysis*Current Transformers* (CT) Ring 800/5A

Table 7. Accuracy of CT Protection 800/5A

No	Primary (A)	Secondary (A)			Accuracy (%)			Error (%)		
		R phase	S phase	T phase	R phase	S phase	T phase	R phase	S phase	T phase
1	32	0.2	0.2	0.2	100	100	100	0	0	0
2	48	0.3	0.3	0.3	100	100	100	0	0	0
3	64	0.4	0.4	0.4	100	100	100	0	0	0
4	80	0.5	0.5	0.5	100	100	100	0	0	0
5	96	0.6	0.6	0.6	100	100	100	0	0	0

The CT Ring installed at the PT PLN (Persero) UP3 Tanjung Priok area substation is a class 5P10 CT Ring with a ratio of 800/5A, according to the IEC 60044-1 standard, the error tolerance limit for class 5P Protection CT is ±1%. The results of the analysis of the 800/5A Protection CT ratio test with class 5P10 show that the Protection CT has an accuracy of above 99 percent, so it can be concluded that the Protection CT is in good condition and does not experience errors above 1% when it is supplied with current according to its nominal current.

4.4 Test AnalysisVoltage Transformer (VT)

a. Test AnalysisVoltage Transformers (VT) Substation KG02

Table 8. Testing the VT Ratio of the KG02 Substation

No	Phase	Primary (Vp)	Secondary (Vs)	VP/ VS	Accuracy (%)	Condition
1	R	11,830	59.2	199.83	99.9	**Good**
2	S	11,900	59.5	200	100	**Good**
3	Q	11,930	59.3	199.83	99.9	**Good**

The VT installed at the KG02 substation is a VT that comes from the Trafindo manufacturer with Type VTI-24-1 with a VT ratio of 20 kV/100 V, where when the primary side of the VT is supplied with a voltage of 20kV then on the secondary side the VT will convert the voltage to 100V where primary to secondary VT ratio is 200V. The analysis results of the 20kV/100V VT ratio test with Type VTI-24-1 show that the VT has an accuracy of above 99 percent, so it can be concluded that the VT is in good condition and can provide voltage to supply TVS to store voltage.

b. Test AnalysisVoltage Transformers (VT) Substation KG180

Table 9. Testing the VT Ratio of the KG180 Substation

No	Phase	Primary (Vp)	Secondary (Vs)	VP/ VS	Accuracy (%)	Condition
1	R	11,720	59.1	198.30	99.3	**Good**
2	S	11,750	59	199.15	99.4	**Good**
3	Q	11,730	59.2	198.14	99.3	**Good**

The VT installed at the KG180 substation is a VT that comes from the Trafindo manufacturer with Type VTI-24-1 with a VT ratio of 20 kV/100 V, where when the primary side of the VT is supplied with a voltage of 20kV then on the secondary side the VT will convert the voltage to 100V where primary to secondary VT ratio is 200V. The analysis results of the 20kV/100V VT ratio test with Type VTI-24-1 show that the VT has an accuracy of above 99 percent, so it can be concluded that the VT is in good condition and can provide voltage to supply TVS to store voltage.

4.5 Test AnalysisTVS

a. Test AnalysisTVS Substation KG02

Table 10. TVS Voltage Testing of KG02 Substation

BRAND	**INPUT (AC)**		**OUTPUT (DC)**	
MBC	110	220	48	110
Measurable	101	-	56	138
Accuracy				**100%**

The TVS installed in the KG02 substation is a TVS from the MBC manufacturer with 220/110 Vac Input and 48/110Vdc Output. The results of the TVS test analysis with 100Vac input from VT and 110Vdc output show that TVS works well and has 100 percent accuracy, so it is concluded that TVS can provide stable voltage to supply relays and tripping coils when Moment Overcurrent disturbances occur.

b. Test AnalysisTVS Substation KG180

Table 11. TVS Voltage Testing of KG180 Substation

BRAND	**INPUT (AC)**		**OUTPUT (DC)**	
MBC	110	220	48	110
Measurable	101	-	56	138
Accuracy				**100%**

The TVS installed in the KG180 substation is a TVS from the MBC manufacturer with 220/110 Vac Input and 48/110Vdc Output. The results of the TVS test analysis with 100Vac input from VT and 110Vdc output show that TVS works well and has 100 percent accuracy, so it is concluded that TVS can provide stable voltage to supply relays and tripping coils when Moment Overcurrent disturbances occur.

V. Conclusion

Based on analysis of the study on the Use of CT Ring Protection as backup protection for Overcurrent DisordersAt the distribution substation, several conclusions were obtained, namely:

1. Determining the CT value based on the PT PLN (Persero) power contract with consumers is a gap in the failure of the protection system at the PT PLN (Persero) Disjaya distribution substation caused by fault currents. *Overcurrent* due to varying CT values , which have the potential to cause saturation of the CT when it is passed *Overcurrent*.
2. The cause of failure of the protection system at the KG02 substation and KG180 substation is due to transformer saturation when a fault current passes through. This will impact the cactus feeder's trip on July 8 2023 and November 23 2020.
3. Based on the analysis of CT Ring saturation calculations with a ratio of 800/5A at the KG02 substation and KG180 substation, the CT Ring can be a solution to overcome CT saturation when overcurrent fault current passes or the CT Ring will saturate when the fault current reaches 39,272 Amperes.
4. The physical shape of the CT Ring 800/5 is small and round, making it easy to install for additional CT Protection at the KG02 and KG180 substations without changing the construction or value of the existing CT based on the power contract.

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