Over Current Relay Protection System Coordination Analysis and Ground Fault Relay on 20 KV Feeder Substations at Muara Tebo Substation

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Abstract

The distribution system is part of the electric power system that functions to distribute electricity to consumers, so the operation of the protection system requires reliable protection of distribution equipment from disturbances, including over load and short circuit disturbances. To minimize such interference, it is hoped that the protection system can meet the requirements of selectivity, reliability, sensitivity and speed, which depend on the accuracy of setting the security equipment. One of the protection equipment used is Over Current Relay (OCR) and Ground Fault Relay (GFR). In this study, an evaluation analysis of the OCR and GFR settings was carried out on the GI of Muara Tebo. The calculation result of the OCR setting on the Incoming side is TMS = 0.19, while the existing OCR data on the Incoming side is TMS = 0.24. The calculation result of the OCR setting on the feeder side is TMS = 0.14, while the existing OCR data on the feeder side is TMS = 0.11. The GFR setting on the Incoming side is TMS = 0.31, while the existing GFR data on the Incoming side is TMS = 0.45. The result of calculating the GFR setting on the feeder side is TMS = 0.12, while the existing GFR data on the feeder side is TMS = 0.11. The calculation results of relay settings with setting data are not much different or the difference is not too significant. the condition of the relay is still in good condition, the relay can coordinate well between the incoming relay and the feeder relay.

Keywords: ***Over Current Relay, Ground Fault Relay, Setting, Protection System***

Introduction

The need for electricity continues to increase from year to year. Ensuring that electrical energy is distributed properly, there are aspects that need to be considered, one of which is ensuring the availability of sufficient electrical energy with satisfactory quality [1], [2]. Electricity is one of the strategic commodities in the Indonesian economy, because it is widely used by the population, especially for lighting purposes, besides that electricity is also one of the main sources of energy for the industrial sector [3]. In the field of electricity supply, three processes of electricity distribution can be clearly distinguished, namely generation, transmission and distribution which can be considered as production or manufacturing, transmission and retail of electrical energy. Electricity supply companies are increasingly needed. To meet the reliability of the availability and distribution of electrical energy, an adequate protection system is needed.

The protection system is a complete arrangement of protection devices consisting of the main device and other devices needed to perform according to the definition contained in the IEC 6255-20 standard. The protection system setting is intended to ensure the continuity of the system power distribution. To set the protection relay, it must meet requirements such as operating speed, good sensitivity, selectivity, reliability, stability and economic considerations. One of the devices that functions to protect electrical equipment is the Over Current Relay (OCR) and Ground Fault Relay (GFR). Both of these relays are often used as local backup protection in conductor protection, and are used to secure protective equipment from damage due to short circuit currents [4].

In this study, an evaluation analysis of short circuit current calculations was carried out at the Muara Tebo Substation to obtain the Setting values of the Over Current Relay (OCR) and Ground Fault Relay (GFR) on the feeder, the results of which will be compared with the simulation results with the hope that the OCR and GFR relays can work well and in accordance with IEC standards [5].

Literature Review

The electrical power protection system is a protection system installed on electrical equipment in an electrical power system, such as generators, transformers, networks, etc., against abnormal operating conditions in the system itself. These conditions include short circuit currents, overvoltages, overloads, low frequency systems, asynchronous and others. The installation of protection devices on the distribution network is intended to reduce the area of disconnection due to disturbances, to maintain continuity of service in the distribution of electrical power. In its application, the protection system consists of several supporting equipment. Below is a general schematic diagram of the protection system and other supporting equipment used [6].

2.1 Protection System Requirements

To prevent the possibility of disruption to the electric power distribution system, it is necessary to carry out protection on a system in the form of a protection relay. With the high cost of equipment in the system, good security to maintain the equipment is needed. If damage occurs, there will be a significant loss, so a reliable protection system is needed. The purpose of the protection system itself is to be able to avoid equipment damage due to short circuit and overload disturbances, at the speed/response level of the protection device, the impact of disturbances on equipment damage will be reduced. In addition, the system is able to locate areas affected by the disturbance, so that it does not spread to other areas or regions. For this purpose, it is expected to provide electricity services with high reliability to consumers. For the operation of protection relays in the electric power system, several requirements are required, namely sensitivity, selectivity, speed, reliability and *Simplicity* [7].

2.2 Short Circuit Disturbance

A short circuit fault is an abnormal relationship in impedance between two points that have different potentials. Short circuit faults that usually occur in distribution networks are:

a. 3-phase short circuit fault.
b. Phase-phase short circuit fault.
c. 1-phase short circuit fault to ground.

Short circuit fault analysis is needed to study the electric power system both during planning and after operation. Short circuit analysis is used to determine the protection relay settings used to protect the electrical system from possible disturbances. The calculation of short circuit fault current aims to analyze a power network system so that the electrical quantities produced from the short circuit fault can be obtained [8].

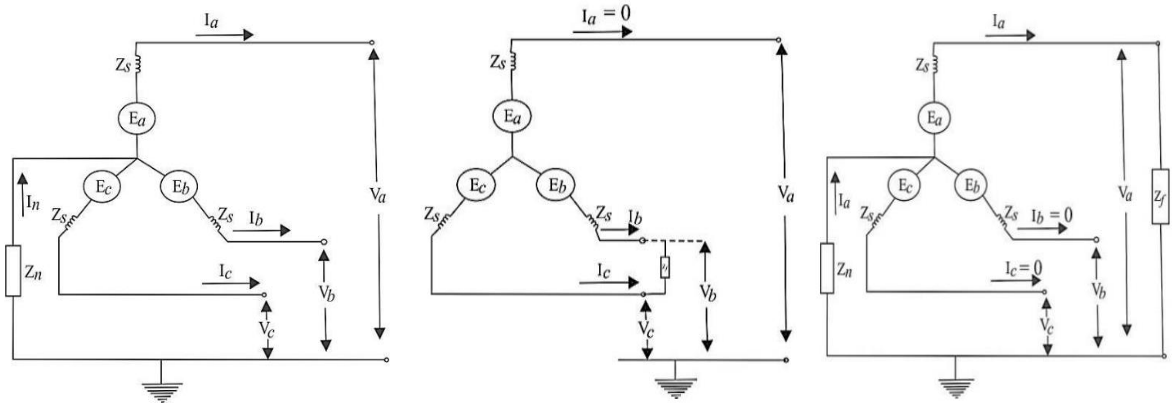

Figure 1. (a) phase short circuit fault, (b) Phase-phase short circuit fault, (c) 1-phase short circuit fault to ground.

The short circuit current of 3 phases, phase-phase, and single phase to ground, the fault current can be calculated using the general equation (Ohm's Law) as follows:

$$I = \frac{V}{Z}$$

In order to differentiate between three-phase, second-phase and single-phase to ground short circuit faults, the impedance formed is in accordance with the type of fault that occurs and the voltage that supplies the fault point, so the impedance formed can be explained as follows [9], [8]:

Z for 3 phase fault, Z = Z1
Z for phase-phase interference, Z = Z1 + Z2
Z for 1 phase to ground fault, Z = Z1 + Z2 + Z0

To calculate the source impedance, the first thing to do is to calculate the short circuit power (MVAsc) on the 150 kV side, then calculate the short circuit impedance on the primary side (150 kV side) and on the secondary side (20 kV) as well as the reactance on the power transformer [5]:

$$ZS_{150\ kV} = \frac{KV^2}{MVA_{sc}}$$

Where:
Zs 150kv = Source impedance (150kV side) (ohm)
kV = Primary side voltage of power transformer (kV)
MVASC = Short circuit data on the primary side 150 kV (MVAsc)

Feeder Impedance:
Z1=Z2 = % × feeder length (kms) × Z1 (ohm/kms)
Z0 = % × feeder length (kms) × Z0 (ohm/kms)

Where:
Z1 = Positive sequence impedance (ohms)
Z2 = Negative sequence impedance (ohms)
Z0 = % × feeder length (kms) × Z0 (ohm/kms)

Equivalent Impedance:
Positive sequence and negative sequence (Z1eq = Z2eq)
Z1eq=Z2eq = Zs (20kv) + Xt1 + Z1

Zero sequence (Z0eq)
Z0eq = Xt0 + 3RN + Z0

2.3 Transformer Reactance

Reactance in a power transformer is a resistance that reacts to changes in voltage and current in a power transformer. Impedance in a power transformer is divided into two, namely positive sequence reactance (X1) and negative sequence reactance (X2), in a power transformer it is listed on the nameplate, the values of X1 and X2 usually range from 10-14%. Next, to calculate the reactance in the transformer Xt (ohm) use the formula [4]:

$$Z_{t100\%} = \frac{KV^2}{MVA_{Trafo}}$$

$$\boldsymbol{X_{t1=t2} = X_{t100\%}\, x\, X_1}$$

Where:
Xt1=t2 = Positive and negative sequence reactance of transformer (ohm)
Xt100% = Transformer reactance at 100% (ohm) X1 = Positive sequence reactance (%)
kV = Transformer secondary voltage (20kV) MVA = Transformer capacity (MVA)

2.4 Protection Relay

A relay is a device that acts as a detector or receiver of a certain quantity and then gives a command in response to the quantity detected by the relay. The quantity in the form of interference then the relay instructs the PMT to disconnect the channel at the point of interference. The working process of the protection relay can be seen in the block diagram below:

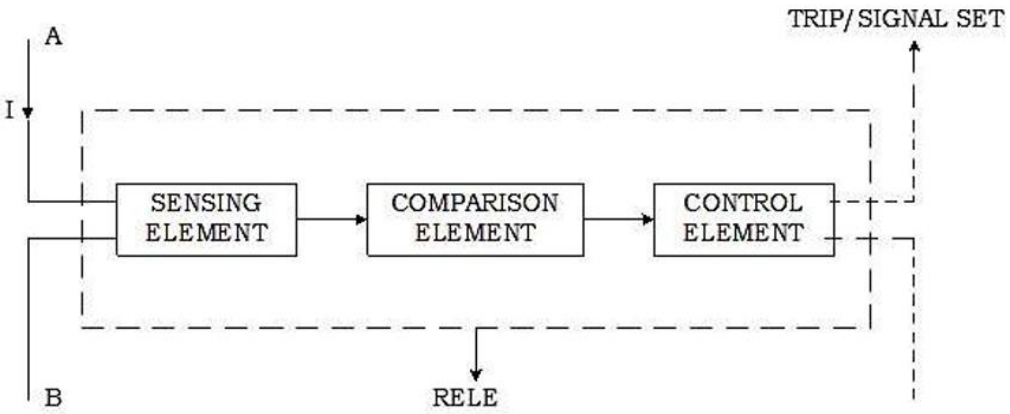

Figure 2. Block Diagram of Protection Relay

2.5 Overcurrent Relay (OCR) and Ground Fault Relay (GFR)

Overcurrent relay or OCR is a type of relay that works based on the magnitude of the input current. If the magnitude of the fault current (Ihs) is greater than the current setting (Iset) the relay will operate. If it does not meet the previous requirements the relay will hold, which means it does not operate. Therefore, the maximum load current must be known to determine whether the ratio of the minimum fault current to the maximum load current is high enough to allow the overcurrent relay used to be operated properly. This overcurrent relay can be used in almost all electrical power safety system, in addition this relay can be used as a primary safety or backup safety. Overcurrent relays are divided into 4 categories, namely instantaneous over-current relays, overcurrent relays with time delay characteristics that do not depend on the magnitude of the short circuit current (definite time over current relay) and overcurrent relays with inverse time delay characteristics (inverse time overcurrent relay).

The working principle of the OCR relay is based on the presence of excess current felt by the relay, either due to short circuit or overload disturbances, which then orders a trip to the PMT according to its operating characteristics.

Research Methodology

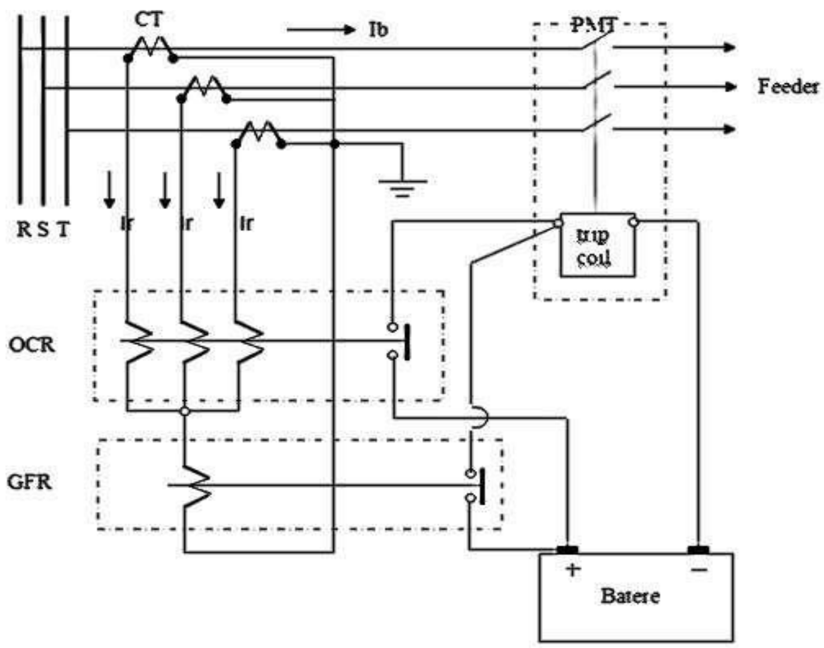

Figure 3. OCR and GFR Relay Wiring Circuit

In this writing it is described, Data were obtained from various references and information related to the research conducted. Sources of information were obtained from published articles, books, theses, and other scientific works.

This method is carried out by means of direct observation and survey in the field and data collection at the Muara Tebo Main Substation to obtain the required data, including: Transformer Specification Data, Over Current Relay (OCR) Specification Data, Ground Fault Relay (GFR) Specification Data, Wire/cable Conductor Type Data, Channel Length Data, Short Circuit Current Data, OCR and GFR Protection Setting Data at the Feeder. The data that has been obtained will be processed to calculate the short circuit power on the 150 kV side bus (MVAsc), then calculate the primary side source impedance (Zs 150kv) and secondary (Zs 20kv), after that calculate the transformer reactance (Xt), then calculate the feeder impedance (Z) and the equivalent feeder impedance (Zeq), then can calculate the short circuit fault current of 3 phases, phase-phase, and 1 phase to ground, after that calculate the current and time settings to get the correct OCR and GFR relay settings so that the relay can work according to the time and provisions.

Table 1. Transformer Specific Data

Parameter	Trafo 1
Merk	UNINDO
Year Of Manufacture	2011
Power Capacity	60 MVA
Impedance	12.50%
Frequency	50 Hz
Primary Voltage	150 KV
Secondary Voltage	20 KV
CT Ratio	2000/5
Nominal Current	1732.05
Transformer Winding Hub	YNyn0(d)
Ground Resistor	12 ohm

Table 2. Wire Type Lengths on Feeders

No	Conductor Type wire/cable	Size	Long
1	Cable AAAC	150 mm^2	12.4 kms

Table 3. Positive/Negative and Zero Sequence Network Impedances

No	Type of Wire/Cable Conductor	Positive/Negative Sequence Impedance (Z1)	Zero Sequence Impedance (Z0)
1	Kawat AAAC	0.2162 + j0.3305	0.3631 + j1.618

Table 4. OCR and GFR Data

Incoming Side OCR Data	GFR Data Incoming Side	Feeder Side OCR Data	Feeder Side GFR Data
Brand: Schneider Type: MICOM P141 Serial No: 31694797 Characteristics: Standard Inverse (SI) I Nominal: 5 CT ratio: 2000/5	Brand: Schneider Type: MICOM P141 Serial No: 31694797 Characteristics: Standard Inverse (SI) I nominal: 0.3 CT ratio: 2000/5	Brand: Schneider Type:MICOM P142 Serial No:31716837 Characteristics: Standard Inverse (SI) I nominal: 3 CT ratio: 800/5	Brand: Schneider Type: MICOM P142 Serial No: 31716837 Characteristics: Standard Inverse (SI) I nominal: 0.5 CT ratio : 800/5

Table 5. Data *Setting* Relay OCR GI

No	Side	***Setting Over Current Relay* (OCR)**				
		I >	I >>	TMS >	**TMS >>**	Kurva
1	*Incoming* 20 kv	2000	-	0,24	-	SI
2	*Feeder*	480	3400	0,11	0,06	SI

Table 6. Data *Setting* Relay GFR GI

No	**Side**	***Setting Ground Fault Relay* (GFR)**				
		I >	I >>	TMS >	TMS >>	Kurva
1	*Incoming* 20 kv	120	-	0,45	-	SI
2	*Feeder*	80	800	0,11	0,1	SI

Results

Network Impedance Calculation

Based on the short circuit current data on the 150kv side bus at the Muara Tebo substation is 25 kA, then the short circuit power on the primary side bus (150kV) can be calculated as follows:

$$MVA_{sc} = I_{sc} \times KV(\text{primer side}) \times \sqrt{3}$$
$$= 25 \times 150 \times \sqrt{3}$$
$$= 6495\ MVA$$

$$ZS_{150\ kV} = \frac{KV_{(\,primer\ side)}{}^2}{MVA_{sc}} = \frac{150^2}{6495} = 3{,}4641\ Ohm$$

$$ZS_{20\ kV} = \frac{KV_{(sekunder\ side)}{}^2}{KV_{(primer\ side)}{}^2}\ x\ 150\ kV = \frac{20^2}{150^2}\ x\ 3{,}464 = 0{,}061\ Ohm$$

Transformer Reactance
To find the positive/negative sequence and zero sequence transformer reactance values, you can use the transformer resistance technical data obtained from the 150 kV GI. The impedance value is 12.50%, the impedance value calculation at 100% condition uses the equation below:

$$X_{t100\,\%} = \frac{{KV_{(sekunder\ side)}}^2}{MVA\ trafo} = \frac{20^2}{60} = 6{,}67\ Ohm$$

Xt1= t2 = Xt100% × X1
X_{t1} = 6,67 x 12,50%
X_{t1} = 0,8333 ohm

For a TD1 power transformer with a YY winding connection and no windings in it, the size of Xt0 ranges from 9 to 14 x Xt1 So:

X_{t0} = 10 × X_{t1}
X_{t0} = 10 × 0,8333
X_{t0} = 8,33 ohm

Feeder Impedance
The impedance values of the feeder on the feeder are as follows:
The positive sequence feeder impedance of 12.4kms (100%) is:
Z1 = Z1 (ohm/kms) × 12.4kms
= (0.2162 + j0.3305) × 12.4 = 2.6809 + j4.0982

Zero sequence feeder impedance
The zero sequence feeder impedance along 12.4kms (100%) is:

Z0 = Z0 (ohm/kms) × 12.4kms
= (0,3631 + j1,618) × 12.4
= 4.5024 + j20.0632

Positive/negative sequence equivalent impedance
Z1eq = Z2eq = Zs 20kv + Xt1 + Z1
= j0.061 + j0.8333 + 2.6809 + j4.0982
= 2.6809 + j4.9931

Before calculating the three-phase and inter-phase short circuit current, the imaginary number (R+jX) in the positive sequence equivalent impedance must first be converted into a real number:

Z1eq (1%) = $\sqrt{R^2 + jX^2}$
= $\sqrt{0.0268^2 + 0.9359^2}$
= 0.93628299 ohm

The positive sequence equivalent impedance over a length of 12.4kms (100%) is:
Z0eq = Xt0 + 3.RN + Z0
= j8.333 + 3×12 + 4.5024 + j20.0632
= 40.5024 + j28.3965

Before calculating the single-phase short circuit current, the imaginary number (R+jX) in the zero sequence equivalent impedance must first be converted into a real number, so that:

$$Z0eq\ (1\%) = \sqrt{R^2 + jX^2}$$
$$= \sqrt{36.0450^2 + 8.5340^2}$$
$$= 37{,}04149495\ ohm$$

Based on the calculations above, the results of the positive and negative sequence impedance are as follows So the following results are obtained:

Table 7. Transformer Reactance and Impedance

Feeder Length		$Z1 = Z2$ (ohm)	$Z0$ (ohm)	$Z1eq$ (ohm)	$Z0eq$ (ohm)
%	Km				
1	0.124	0.0268 + j0.0410	0.0450 + j0.2006	0.0268 + j0.9359	36.0450 + j8.5340
5	0.62	0.134 + j0.2049	0.2251 + j1.0032	0.134 + j1.0998	36.2251 + j9.3365
10	1.24	0.2681 + j0.4098	0.4502 + j2.0063	0.2681 + j1.3047	36.4502 + j10.3397
15	1.86	0.4021 + j0.6147	0.6754 + j3.0095	0.4021 + j1.5096	36.6754 + j11.3428
20	2.48	0.5362 + j0.8196	0.9005 + j4.0126	0.5362 + j1.7146	36.9005 + j12.3460
25	3.10	0.6702 + j1.0246	1.1256 + j5.0158	0.6702 + j1.9195	37.1256 + j13.3491
30	3.72	0.8043 + j1.2295	1.3507 + j6.0190	0.8043 + j2.1244	37.3507 + j14.3523
35	4.34	0.9383 + j1.4344	1.5759 + j7.0221	0.9383 + j2.3293	37.5759 + j15.3555
40	4.96	1.0724 + j1.6393	1.8010 + j8.0253	1.0724 + j2.5342	37.8010 + j16.3586
45	5.58	1.2064 + j1.8442	2.0261 + j9.0284	1.2064 + j2.7391	38.0261 + j17.3618
50	6.20	1.3404 + j2.0491	2.2512 + j10.0316	1.3404 + j2.9440	38.2512 + j18.3649
55	6.82	1.4745 + j2.2540	2.4763 + j11.0348	1.4745 + j3.1489	38.4763 + j19.3681
60	7.44	1.6085 + j2.4589	2.7015 + j12.0379	1.6085 + j3.3538	38.7015 + j20.3713
65	8.06	1.7426 + j2.6638	2.9266 + j13.0411	1.7426 + j3.5587	38.9266 + j21.3744
70	8.68	1.8766 + j2.8687	3.1517 + j14.0442	1.8766 + j3.7637	39.1517 + j22.3776
75	9.30	2.0107 + j3.0737	3.3768 + j15.0474	2.0107 + j3.9686	39.3768 + j23.3807
80	9.92	2.1447 + j3.2786	3.6020 + j16.0506	2.1447 + j4.1735	39.6020 + j24.3839
85	10.54	2.2787 + j3.4835	3.8271 + j17.0537	2.2787 + j4.3784	39.8271 + j25.3871
90	11,16	2.4128 + j3.6884	4.0522 + j18.0569	2.4128 + j4.5833	40.0522 + j26.3902
95	11.78	2.5468 + j3.8933	4.2773 + j19.0600	2.5468 + j4.7882	40.2773 + j27.3934
100	12.4	2.6809 + j4.0982	4.5024 + j20.0632	2.6809 + j4.9931	40.5024 + j28.3965

Calculating Short Circuit Current
After the equivalent impedance is obtained according to the fault location, then the short circuit current can be calculated using the basic formula explained previously.

Calculation of 3-Phase Short Circuit Current

$$I_{f\ 3\emptyset} = \frac{V_{LN}}{Z_{1e}} = \frac{\frac{20000}{\sqrt{3}}}{Z_{1eg}}$$

$$I_{f\ 3\emptyset\ (1\%)} = \frac{11547}{Z_{1eg(1\%)}}$$

$$= \frac{11547}{0{,}936282998} = 12332{,}8\ A$$

Calculation of Phase-Phase Short Circuit Current
The basic formula used to calculate the value of short circuit current is:

$$I_{f\ 2\emptyset} = \frac{V_{ll}}{Z_{1eg} + Z_{2eg}}$$

$$I_{f\ 2\emptyset(1\%)} = \frac{20000}{2\ x\ 0{,}936282998} = 10680{,}5\ A$$

Calculation of Single Phase Short Circuit Current to Ground
The basic formula used to calculate the value of short circuit current is

$$I_{f\ 1\emptyset} = \frac{3\ x\ \frac{20000}{\sqrt{3}}}{Z_{1eg} + Z_{2eg} + Z_{0eg}}$$

$$= \frac{3\ x\ 11547}{(2xZ_{1eg} + Z_{2ea)}}$$

$$= \frac{3\ x\ 11547}{(2x0{,}936282998) + 37{,}04149495}$$

$$= 922{,}1\ A$$

The same thing is done to calculate the disturbances in the other feeders, so that we get:

Table 8. Equivalent Impedance and Short Circuit Fault

Feeder Length		Z_{0eq} (ohm)	Z_1 (ohm)	Z_0 (ohm)	3 Phase	Phase-Phase	1 Phase to ground
%	Km						
1	0.124	36.0450 + j8.5340	0,936282998	37,04149495	12332.8	10680.5	922.1
5	0.62	36.2251 + j9.3365	1,107960390	37,40895042	10421.9	9025.6	905.1
10	1.24	36.4502 + j10.3397	1,331997445	37,88837181	8668.9	7507.5	884.0
15	1.86	36.6754 + j11.3428	1,562280246	38,38934599	7391.1	6400.9	863.1
20	2.48	36.9005 + j12.3460	1,796445765	38,91104049	6427.7	5566.5	842.5
25	3.10	37.1256 + j13.3491	2,033106735	39,45263335	5679.5	4918.6	822.2
30	3.72	37.3507 + j14.3523	2,271536411	40,01331659	5083.3	4402.3	802.4

35	4.34	37.5759 + j15.3555	2,511172337	40,59229916	4598.3	3982.2	783.0
40	4.96	37.8010 + j16.3586	2,751762713	41,18880936	4196.2	3634.0	764.2
45	5.58	38.0261 + j17.3618	2,993010207	41,80209687	3858.0	3341.1	745.9
50	6.20	38.2512 + j18.3649	3,234796808	42,43143419	3569.6	3091.4	728.1
55	6.82	38.4763 + j19.3681	3,477052456	43,07611789	3320.9	2876.0	710.8
60	7.44	38.7015 + j20.3713	3,719609832	43,73546934	3104.4	2688.5	694.2
65	8.06	38.9266 + j21.3744	3,962491331	44,40883519	2914.1	2523.7	678.0
70	8.68	39.1517 + j22.3776	4,205561116	45,09558767	2745.7	2377.8	662.4
75	9.30	39.3768 + j23.3807	4,448869676	45,79512454	2595.5	2247.8	647.3
80	9.92	39.6020 + j24.3839	4,692297026	46,50686892	2460.8	2131.2	632.7
85	10.54	39.8271 + j25.3871	4,935863611	47,23026889	2339.4	2026.0	618.6
90	11,16	40.0522 + j26.3902	5,179596369	47,96479713	2229.3	1930.7	605.0
95	11.78	40.2773 + j27.3934	5,423386394	48,70995019	2129.1	1843.9	591.9
100	12.4	40.5024 + j28.3965	5,667313808	49,46524792	2037.5	1764.5	579.2

Setting OCR and GFR at the Substation

Setting OCR
Setting Current

Iset Primer = 1,05 × Iload
= 1,05 × 457
= 480 A

Iset Sekunder = Iset primer × Ratio CT

$$= 480\ \frac{5}{800} = 5\ A$$

***Setting* TMS (Time Delay)**

$$TMS = \frac{\frac{tx\ If^{0,02} - 1}{Iset}}{0,14} = \frac{\frac{0,3\ x\ 12332,8\ x\ 0,02^{0,02}}{480}}{0,14} = 0,14$$

$$t = \frac{tms\ x\ 0,14}{\frac{If\ 0,02}{(Iset) - 1}} = \frac{0,14\ x\ 0,14}{\frac{12332,8\ x\ 0,02}{(480) - 1}} = 0,3$$

Setting GFR
Setting Current

Iset Primer = 10% × 579,2
= 1,05 × 579,2
= 57,92 A

Iset Sekunder = Iset primer × Ratio CT

$$= 57{,}92\ \frac{5}{800} = 0{,}36\ A$$

***Setting* TMS (Time Delay)**

$$TMS = \frac{\frac{tx\ If^{0,02}-1}{Iset}}{0{,}14} = \frac{\frac{0{,}3\ x\ 922{,}1x\ 0{,}02}{57{,}92}}{0{,}14} = 0{,}12\ A$$

$$t\ = \frac{tms\ x\ 0{,}14}{\frac{If\ 0{,}02}{(Iset)-1}} = \frac{0{,}12\ x\ 0{,}14}{\frac{922{,}1\ x\ 0{,}02}{(57{,}92)-1}} = 0{,}3\ A$$

Setting OCR and GFR Side Incoming

Setting OCR
Setting Current

$$I_{Load} = \frac{MVA}{\text{KV} \times \sqrt{3}} = \frac{60000}{20 \times \sqrt{3}} = 1732{,}05$$

Iset Primer = 1,05 × Ibeban
= 1,05 × 1732,0 = 18181,65 A

Iset Sekunder = Iset primer × Ratio CT

$$= 18181{,}65\ \ \frac{5}{2000} = 4{,}546\ A$$

***Setting* TMS (Time Delay)**

$$TMS = \frac{\frac{tx\ If^{0,02}-1}{Iset}}{0{,}14} = \frac{\frac{0{,}7\ x\ 12332{,}8\ x\ 0{,}02^{0,02}}{1818{,}65}}{0{,}14} = 0{,}19$$

$$t\ = \frac{tms\ x\ 0{,}14}{\frac{If\ 0{,}02}{(Iset)-1}} = \frac{0{,}19\ x\ 0{,}14}{\frac{12332{,}8\ x\ 0{,}02}{(480)-1}} = 0{,}7\ A$$

Setting GFR
Setting Current
Iset Primer = 8% × 579,2
= 0,08 × 579,2 = 46,33 A

Iset Sekunder = Iset primer × Ratio CT

$$= 46{,}33\ \frac{5}{800} = 0{,}12\ A$$

***Setting* TMS (Time Delay)**

$$TMS = \frac{\frac{tx\ If^{0,02} - 1}{Iset}}{0,14} = \frac{\frac{0,7\ x\ 922,1\ x\ 0,02}{46,33}}{0,14} = 0,31$$

$$t = \frac{tms\ x\ 0,14}{\frac{If\ 0,02}{(Iset) - 1}} = \frac{0,31\ x\ 0,14}{\frac{922,1\ x\ 0,02}{(46,33) - 1}} = 0,7\ A$$

Table 9. Trip Time for 3-Phase Fault Relay on Incoming and Feeder Sides

Location Disruption		Fault Current (Ampere)	Relay Trip Time on fault (seconds)		
%	Distance (km)	3 Phase	*Incoming*	*Feeder*	Time Difference
1	0.124	12332.8	0.70	0.30	0.4
5	0.62	10421.9	0.77	0.31	0.46
10	1.24	8668.9	0.86	0.33	0.53
15	1.86	7391.1	0.96	0.35	0.61
20	2.48	6427.7	1.07	0.37	0.7
25	3.10	5679.5	1.19	0.39	0.8
30	3.72	5083.3	1.31	0.41	0.9
35	4.34	4598.3	1.46	0.43	1.03
40	4.96	4196.2	1.62	0.45	1.17
45	5.58	3858.0	1.80	0.47	1.33
50	6.20	3569.6	2.01	0.49	1.52
55	6.82	3320.9	2.25	0.50	1.75
60	7.44	3104.4	2.54	0.52	2.02
65	8.06	2914.1	2.88	0.54	2.34
70	8.68	2745.7	3.30	0.56	2.74
75	9.30	2595.5	3.82	0.58	3.24
80	9.92	2460.8	4.50	0.60	3.9
85	10.54	2339.4	5.41	0.62	4.79
90	11,16	2229.3	6.69	0.64	6.05
95	11.78	2129.1	8.65	0.66	7.99
100	12.4	2037.5	12.00	0.68	11.32

Table 10 Phase-Phase Fault Relay Trip Time on Incoming and Feeder Sides

Location Disruption		Fault Current (Ampere)	Relay Trip Time on fault (seconds)		
%	Distance (km)	Phase-Phase	*Incoming*	*Feeder*	Time Difference
1	0.124	10680.5	0.76	0.31	0.45
5	0.62	9025.6	0.84	0.33	0.51
10	1.24	7507.5	0.95	0.35	0.6
15	1.86	6400.9	1.07	0.37	0.7
20	2.48	5566.5	1.21	0.40	0.81
25	3.10	4918.6	1.36	0.42	0.94
30	3.72	4402.3	1.53	0.44	1.09
35	4.34	3982.2	1.73	0.46	1.27
40	4.96	3634.0	1.96	0.48	1.48
45	5.58	3341.1	2.23	0.50	1.73
50	6.20	3091.4	2.56	0.52	2.04
55	6.82	2876.0	2.96	0.55	2.41
60	7.44	2688.5	3.48	0.57	2.91
65	8.06	2523.7	4.15	0.59	3.56
70	8.68	2377.8	5.08	0.61	4.47
75	9.30	2247.8	6.43	0.63	5.8
80	9.92	2131.2	8.59	0.66	7.93
85	10.54	2026.0	12.63	0.68	11.95
90	11,16	1930.7	22.81	0.70	22.11
95	11.78	1843.9	102.61	0.73	101.88
100	12.4	1764.5	-	0.75	0.75

Table 11 Trip Time for 1 Phase Fault Relay to Ground on Incoming and Feeder Sides

Location Disruption		Fault Current (Ampere)	Relay Trip Time on fault (seconds)		
%	Distance (km)	1 Phase to Ground	*Incoming*	*Feeder*	Time Difference

1	0.124	922.1	0.70	0.30	0.4
5	0.62	905.1	0.70	0.30	0.4
10	1.24	884.0	0.71	0.30	0.41
15	1.86	863.1	0.72	0.31	0.41
20	2.48	842.5	0.72	0.31	0.41
25	3.10	822.2	0.73	0.31	0.42
30	3.72	802.4	0.73	0.31	0.42
35	4.34	783.0	0.74	0.32	0.42
40	4.96	764.2	0.75	0.32	0.43
45	5.58	745.9	0.75	0.32	0.43
50	6.20	728.1	0.76	0.33	0.43
55	6.82	710.8	0.77	0.33	0.44
60	7.44	694.2	0.78	0.33	0.45
65	8.06	678.0	0.78	0.34	0.44
70	8.68	662.4	0.79	0.34	0.45
75	9.30	647.3	0.80	0.34	0.46
80	9.92	632.7	0.80	0.35	0.45
85	10.54	618.6	0.81	0.35	0.46
90	11,16	605.0	0.82	0.35	0.47
95	11.78	591.9	0.82	0.36	0.46
100	12.4	579.2	0.83	0.36	0.47

Conclusion

Based on the calculation results that have been carried out, the following conclusions can be drawn:

1. The peak load that occurs on the analyzed transformer occurs at night with a loading of 32% while the percentage of loading during the day is 2.04%.
2. Based on the results of the calculation analysis of the value of power losses that caused by neutral current during the day is 0.037 kVA with a percentage of 0.02%, while at night it is 0.34 kVA with a percentage of 0.22.
3. The results of the analysis of the calculation of the value of power losses caused by grounding current during the day are 0.256 kVA with a percentage of 0.16%, while at night it is 0.586 kVA with a percentage of 0.3%.
4. Based on the results of the analysis, the amount of kWH saved in the medium voltage network is 124.2209 while the percentage of shrinkage reduction in the low voltage network after being balanced, at peak load times is 84% and outside peak load times is 73%.

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