www.bircu-journal.com/index.php/birci
Budapest International Research and Critics Institute-Journal (BIRCI-Journal)
Humanities and Social Sciences
ISSN 2615-3076 Online)
ISSN 2615-1715 (Print)
Budapest Institute

Evaluation Analysis of OCR and GFR Relay Protection Coordination on Feeder YB-02 PT PLN ULP Natal with ETAP Simulation

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Abstract

With the increasing number of customers of PT. PLN (Persero) ULP Natal, disruption to the distribution system will result in more widespread blackouts. To avoid this, the protection system in the distribution channel (especially in the YB-02 feeder) needs to be evaluated to ensure proper coordination. The protection systems are outgoing PMT, Recloser L-01 and Recloser L-02. The method used in this study is a method of observation, literature study, interviews and guidance. From this study, it was found that the coordination conditions between PMT Outgoing, Recloser L-01 and Recloser L-02 were correct and their capabilities could be improved by calculating the OCR and GFR relay settings. The coordination between PMT Outgoing.

Keywords
distribution protection; coordination and protection settings; OCR; GFR; recloser; PMT

I. Introduction

Electrical energy is one of the most vital needs in the modern era like now. In this case, PT. PLN (Persero) as the company authorized to supply electrical energy needs to provide guaranteed electrical energy. The provision of electrical energy is carried out by an electric power system which includes a generation system, transmission system, and distribution system. To ensure continuity of electrical energy service, a high level of reliability is required for each element of the electric power system.

The distribution system is the part of the electric power system that is closest to the customer, so a disturbance in the distribution system will have a direct impact on the customer. Disturbances in the electric power system can cause equipment to become damaged so that it interferes with service to consumers or customers. payment methods used namely the retrospective payment method and the prospective payment method (Herianti, 2020). Saputra (2018) statet that implications for the need to develop financing standards that include standardization of education cost components covering operational costs, investment costs and personal costs. Therefore, it is necessary to make efforts to secure the electric power system so that the reliability in the supply of electricity goes well. For this reason, it is necessary to design a security system in the distribution system.

In 2020 the Panyabungan Substation operates to supply PLN ULP Natal which previously received supplies from the Panyabungan Substation. With the change in supply, PLN ULP Natal made changes to the network configuration in order to maintain the reliability of the distribution system in distributing electrical power to the community.

One of the most important things to pay attention to is the change in the configuration of the feeder network, namely the coordination between security equipment in the distribution security system. Coordination between safety equipment in a distribution security system is very important to determine the reliability of a feeder to secure distribution system equipment and/or localize faults. To determine a setting or coordination of safety equipment against interference, it is necessary to know the amount of short-circuit current in the distribution network. With the increasing number of customers every year, it will certainly affect the number of customers who experience blackouts due to disturbances. Therefore, an action is needed to maintain the security settings and coordination in order to maintain its reliability.

II. Research Methods

This research will be conducted at PT PLN (Persero) ULP CHRISTMAS UP3 Padangsidimpuan North Sumatra Region. This research was conducted in May 2020 until the end of July 2020.

Figure 1. *Research Flowchart*

Figure 1 is a flowchart of research implementation in general, the preparation of this research is depicted in a flowchart. Starting with conducting a data survey at PT PLN (Persero) ULP Natal. After the data is collected, make a modeling of the Natal ULP network on the ETAP software. Then the next step is to enter the existing data into the network model that has been created. Furthermore, with the existing data that has been obtained, a manual short-circuit current calculation is made in the ULP Natal distribution system. Then simulate the short circuit current on the model that has been made using ETAP software. Then a comparison of the results of manual calculations with the ETAP simulation is carried out. After the short circuit current has been simulated, the OCR and GFR relay protection settings are made manually then the results of these calculations are input into the ETAP network modeling that has been made. Furthermore, a simulation of the coordination of OCR and GFR relay protection is carried out in securing short-circuit disturbances that occur in the ULP Natal distribution system network. Evaluation of the simulation results of the OCR and GFR relay coordination on the existing results of the resetting that has been made.

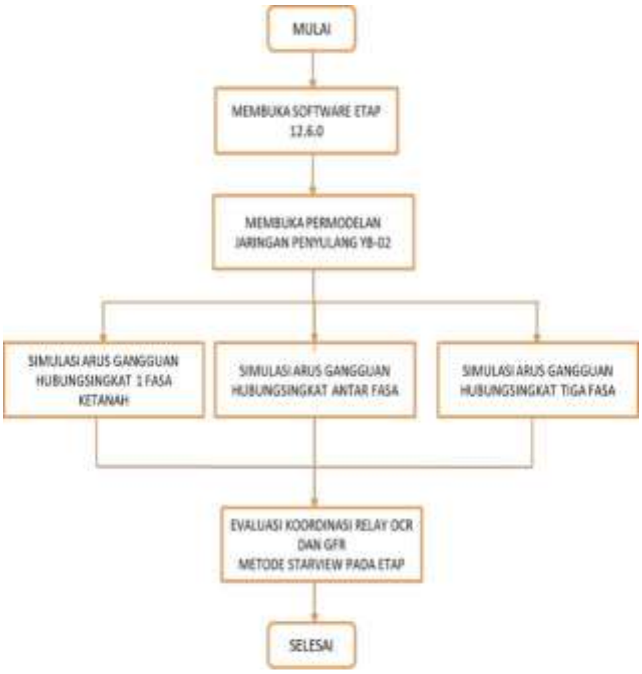


Figure 2. *Stage Simulation Flowchart*

Figure 2 is a flow diagram of the OCR and GFR relay coordination simulation in ETAP software, starting with opening the ETAP 12.6.0 software then opening the YB-02 feeder network modeling, then performing 3 short circuit fault current simulations, namely:

I. Simulation of 1 Phase Ground Short Circuit Fault
II. Inter-phase short circuit fault simulation
III. Simulation of Three-Phase Short-circuit Fault Then evaluate the coordination of the OCR and GFR relays in securing short-circuit faults in each simulation of short-circuit current faults.

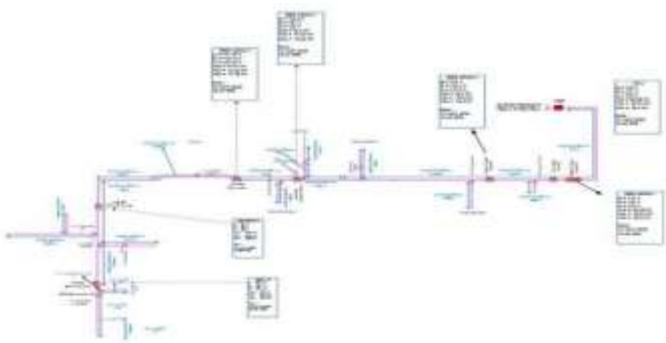


Figure 3. *Single Diagram PLN Natal*

From the Single Line Diagram ULP Natal data above, it can be seen that the distribution network equipment used is a power transformer at a 60 MVA substation, a 16-250 kVA distribution transformer, a circuit breaker, a recloser, a load breaker switch, a disconnecting switch, conductor wire and its type and length.

III. Discussion

3.1 Total Network Impedance Calculation Results

The following is a table of the results of the calculation of the impedance value of the zero sequence, the positive sequence and the negative sequence as a reference in calculating the short circuit current. The following is an example of a calculation for a 100% distance point:

$$Z1Tot = Z2Tot = Z_{1S} + Z1t + Z1SAL240$$

$$= ++8.99 + j19.73j0,09647\ j2,0092$$

$$Z1Tot = Z2Tot = 8.99 + j21.84 \text{ Ohm}$$

Table 1. Calculation of Total Impedance

Network Length		Positive and Negative Order [Ohms]		Zero Sequence [Ohms]	
%	KM	R	X	R	X
0	0.00	0.00	2.11	0.90	6.03
25	15.63	2.10	7.02	14.24	24.46
50	31.25	4.20	11.97	27.59	42.89
75	46.88	6.30	16.91	40.93	61.32
100	62.50	8.99	21.84	54.27	79.75

3.2 Short Circuit Current Calculation Results

Three-phase short-circuit current calculation Using equation (2.49):

$$I_{a1} = \frac{Ea}{Z}$$

$$I_{a1} = \frac{1 \quad 1\angle 0^\circ}{2,2475+j5,46}$$

$I_{a1}=0,169\angle -67,66^\circ pu$ (for a network length of 62.5 km)

Three-phase short circuit in the system at the end of the network (62.5 km) can be determined by entering the above results into equation (2.50):

$I_a = I_{a1}$

$I_a = 0{,}169$ pu

3.3 Current Calculation Short Circuit between Phases

By using equation (2.46):

$$I_{a1} = \frac{Ea}{Z_1 + Z_2}$$

$$I_{a1} = \frac{1}{(2{,}2475+j5{,}45) + (2{,}2475+j5{,}45)}$$

$I_{a1} = 0{,}085\angle{-67{,}76°}$pu (for network length 21.55 km)

The short circuit between the phases in the system at the end of the network (21.55 km) can be determined by entering the above results into equation (2.47).

$I_b = a^2 I_{a1} + a I_{a2}$

Substitute equation (2.45) into equation (2.47):

$I_b = a^2 I_{a1} + a(-I_{a1})$

$I_b = a^2 I_{a1} - a I_{a1}$

$I_b = I_{a1}(a^2 - a)$

$I_b = 0{,}085(\sqrt{3})$ –

$I_b = 0{,}147$pu

Plugging the above values into equation (2.53):

$I_b = 0{,}147 \times 2886{,}4$ A

$I_b = 425{,}405$ A

3.4 Current Calculation Single Phase Short Circuit to Ground

By using equation (2.32):

$$I_{a1} = \frac{Ea}{Z_1 + Z_2 + Z_0}$$

$I_{a1} = 0{,}0856\angle{-69{,}31°}$pu

(for a network length of 62.5 km)

Single-phase short circuit to ground in the system at the end of the network (62.5 km) can be determined by entering the above results into equation (2.33)

$I_a = 3I_{a1}$

$I_a = 3(0,0856)$

$I_a = 0,147$ pu

Plugging the above values into equation (2.53):

$I_b = 0,147 \times 2886,4$ A

$I_b = 425,405$ A

Table 2. The Results of the Calculation of the Short Contact Current

Channel Length		Short Circuit Current [Amperage]		
%	KM	3 phase	2 phase	1 Phase to Ground
0	0.00	5550.77	4783.18	3369.34
25	15.63	1578.13	1372.97	811.55
50	31.25	964.71	839.29	456.47
75	46.88	641.42	558.04	317.30
100	62.50	488.97	425.41	242.22

3.5 Settings OCR and GFR (Calculation)

Settings OCR and GFR calculation aims to get the best setting value. In this problem, it is expected to improve and/or improve the coordination and workability of OCR and GFR on the JJR-02 feeder.

Settings OCR (Calculation)

a. Recloser settings L-02

Isetprimary = $1.2 \times I_{max\ load}$

$= 1.2 \times 120$ A

$= 144$A

Secondary Iset = $I_{primaryset} X$

ratio CT

$= 144 \times 1/1000$

$= 0,144$ A

x CT Ratio on

Recloser

h = 678 × 1/1000

h = 0,678 A

So, from the above calculation results can be obtained the value of TMS Recloser as follows:

Data : t = 0.3 seconds

$I_{hs\ secondary\ between\ phases}$ = 0.678

A

$I_{secondary\ set}$ = 0.144 A

So, TMS Recloser is:

$$TMS = \frac{t \times \left[\left[\frac{I_{hs\ sekunder\ antarfasa}}{I_{set\ sekunder}}\right]^{0,02} - 1\right]}{0,14}$$

$$TMS = \frac{0,3 \times \left[\left[\frac{0,678}{0,144}\right]^{0,02} - 1\right]}{0,14}$$

TMS = 0.0675

Primary instantRecloser = Ihs 3 phase point 100% = 680 A

Secondary instantRecloser = $I_{primary\ instant}$x ratio CT

= 680x 1/1000

= 0.68 A

b. Recloser settings L-01

Isetprimary = 1.05 x $I_{max\ load}$

= 1.05 x 200 A

=210A

Secondary Iset ratio = $I_{primary\ set}$X

CT

= 210 x 1/1000

= 0,21 A

h =

h x CT Ratio on Recloser

$h \quad = 1198 \times 1/1000$

$h \quad = 1{,}198$ A

So, from the above calculation results can be obtained the value of TMS Recloser as follows:

Data: t = 0.7 seconds

$I_{\text{hs secondary between phases}}$ = 1.198A

$I_{\text{secondary set}}$ = 0.21A

So, TMS Recloser is:

$$TMS = \frac{t \times \left[\left[\frac{I_{hs\ sekunder\ antarfasa}}{I_{set\ sekunder}}\right]^{0,02} - 1\right]}{0,14}$$

$$TMS = \frac{0,7 \times \left[\left[\frac{1,198}{0,21}\right]^{0,02} - 1\right]}{0,14}$$

TMS = 0.175

Primary instantRecloser = Ihs 3 phase point 30% = 1377 A

Secondary instantRecloser = $I_{\text{primary instant}}$ x ratio CT

= 1377x 1/1000

= 1,377 A

*c. Settings*PMT Outgoing

Isetprimary $= 1.05 \times I_{smallest\ nominal}$

$= 1.05 \times 266$ A

$= 280$ A

Secondary Iset ratio $= I_{primary\ set} \times$

CT

$= 280 \times 1/400$

$= 0.70$ A

h $= 1198 \times 1/400$

h $= 2,99$ A

$$TMS = \frac{t \times \left[\left[\frac{I_{hs\ sekunder\ antarfasa}}{I_{set\ sekunder}}\right]^{0,02} - 1\right]}{0,14}$$

$$TMS = \frac{1,1 \times \left[\left[\frac{2,99}{0,7}\right]^{0,02} - 1\right]}{0,14}$$

From the above calculation results, the Outgoing, Recloser L-01 and Recloser L-02 times are obtained as shown in table 3.

Table 3. Recloser L-01 and Recloser L-02 Calculation Levels

%	km	1 Phase Short Circuit Current to ground (A)	PMT Outgoing Working Time(s)	L-01 Recloser Working Time(s)	L-02 Recloser Working Time(s)
0	0	3369.34	0.05		
25	15.6	811.55	2.96	0.03	
50	31.2	456.47	5.05	2.10	
75	46.8	317.30	9.06	3.77	1.36
100	62.5	242.22	21.89	9.12	3.28

So, from the above calculation results can be obtained the value of TMS PMT Outgoing as follows:

Data : t = 1.1 seconds

$I_{\text{hs secondary between phases}}$ = 2.99 A

$I_{\text{secondary set}}$ = 0.7A

3.6 Etap Software Simulation

a. Simulation of Short Circuit 3-Phase Fault at Location 1

Simulation of a 3-phase fault short circuit at location 1 will be carried out on bus 1. In this 3-phase fault simulation, it will be seen the magnitude of the fault current that occurs at bus 1. For more details, Figure 3.37 is the result of a 3phase fault simulation at location 1

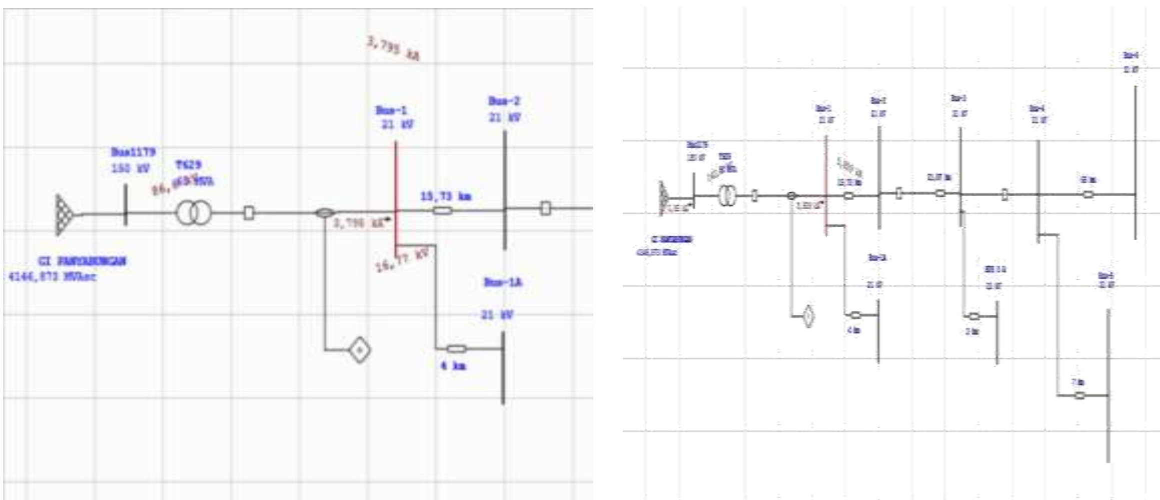


Figure 4. *Simulation of 3 Phase Short Circuit at Location 1*

From the picture above, the results show that when a short circuit occurs on bus 1, the short circuit current that occurs is 5.929 Ka on bus 1. For more details, Figure 3.39 is the result of simulation of inter-phase faults at location 1.

b. Simulation of Inter-Phase Short Circuit Fault at location 1

A short circuit simulation of inter-phase faults at location 1 will be carried out on bus 1. In this inter-phase fault simulation, it will be seen the magnitude of the fault current that occurs at bus 1. For more details, Figure 3.38 is the result of the simulation of inter-phase faults at location 1:

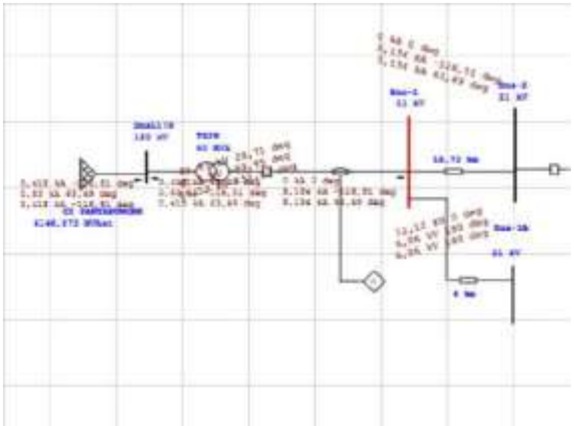


Figure 5. *Simulation of 1 Phase to Ground Fault at Location 1*

From Figure above, the results show that when there is a single-phase short circuit to ground on bus 1, the short circuit current that occurs is 3.88 kA.

c. Safety Coordination on Feeder YB-02

The YB-02 feeder uses several network securities including PMT Outgoing, Recloser L-01 and Recloser L-02. Each security is placed in each security area.

d. Short Circuit Simulation of 1 Phase to Ground Fault at Location 1

Simulation of short-circuit faults between phases at location 1 will be carried out on bus 1. In this simulation of inter-phase faults, it will be seen the magnitude of the fault current that occurs. location of the disturbance, so that the reliability of a network can be better. In order to prove that the safety coordination on the YB-02 feeder that I have set based on my calculations is working properly or not, a simulation must be carried out in each security area, in order to find out whether there is an error in the coordination of the safety on the YB-02 feeder.

In this simulation, what I will do is simulate a 3-phase short circuit at location 1 where the end of location 1 is located on bus 2. At location 1 if there is a 3-phase short- circuit fault that will secure it is PMT Outgoing. Figure 3.69 below is a simulation of safety coordination in area 1 in securing 3- phase faults:

Figure 6. Simulation of 1 Phase to Ground Fault at Location 1

e. Simulation of Coordination of Protection

Equipment in Securing 3-Phase Interference

In this sub-chapter I will simulate interphase faults at 3 locations, namely location 1, location 2, and location 3.

f. Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at Location 1

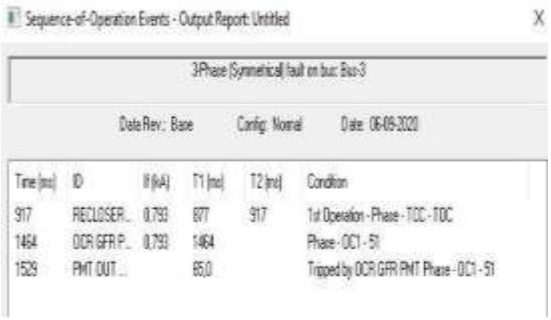
Figure 7 Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at Location 1.

Figure 7. *Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at Location 1*

g. Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at Location 2

From the data above, it is found that when a 3-phase short circuit occurs on bus 2, the short-circuit current that occurs is 1,693 kA. The short circuit current that occurs on bus 2 exceeds the pick up current setting on the OCR so that the OCR will work with a working time of 0.8 seconds. In addition, from the short circuit report data above, we can also see that the working time of opening PMT outgoing is 0.9 seconds. This proves that the coordination of protective equipment at location 3 is good.

In this simulation, what I will do is do a 3-phase short circuit simulation at location 2 where the end of location 2 is located on bus 3. At location 2 if there is a 3-phase short-circuit fault that will secure is Recloser L-01 while PMT Outgoing as back up. Figure 4.44 below is a simulation of safety coordination in area 2 in securing 3-phase faults:



Sequence-of-Operation Events - Output Report: Untitled

3Phase (Symmetrical) fault on bus: Bus-3

Data Rev.: Base   Config.: Normal   Date: 06-09-2020

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
917	RECLOSER...	0.793	877	917	1st Operation - Phase - TOC - TOC
1464	OCR GFR P...	0.793	1464		Phase - OC1 - 51
1529	PMT OUT...		65.0		Tripped by OCR GFR PMT Phase - OC1 - 51

Figure 8. *Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at Location 2*

Figure 9. *Short Circuit Analysis Report at Stages in the Event of a 3-Phase Short circuit fault at the location*

From the data above, it is found that when a 3-phase short circuit occurs on bus 3, the short-circuit current that occurs is 0.793 kA. The short circuit current that occurs on bus 6 exceeds the pick-up current setting on the OCR so that the OCR will work with a working time of 0.9 seconds. In addition, from the short circuit report data above, we can also see that the working time of opening PMT outgoing is 1.5 seconds. This proves that the coordination of protective equipment at location 2 is good.

h. Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at 3 Locations

In this simulation, what I will do is perform a 3-phase short circuit simulation at location 3 where the end of location 3 is located on bus 6. At location 3 if there is a 3-phase shortcircuit fault that will secure is Recloser L-01 plays a role as the first back up and PMT Outgoing as the third back up. Figure 4.46 below is a simulation of safety coordination in area 3 in securing 3-phase faults.

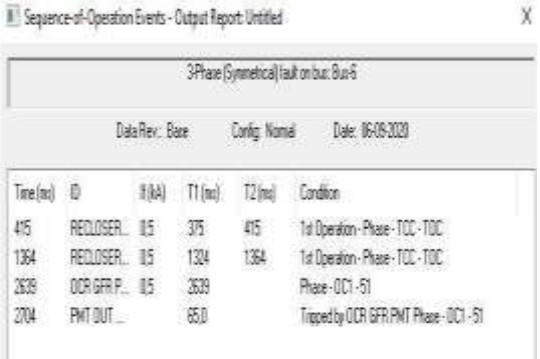


Figure 10. *Simulation of Coordination of Protection Equipment in Securing 3-Phase Faults at Location 3*

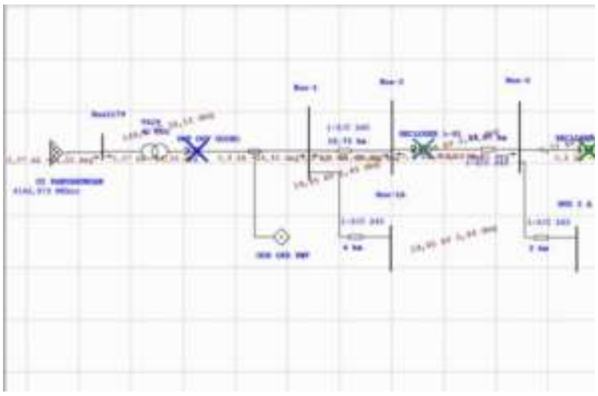


Figure 11. *Short Circuit Analysis Report at Stage If There is a 3-Phase Short Circuit Faults at Location 3*

From the data above, it is found that when a 3-phase short circuit occurs on bus 6, the short circuit current that occurs is 0.5 kA. The short circuit current that occurs on bus 6 exceeds the pick-up current setting on the OCR so that the OCR will work with a working time of 0.4 seconds. In addition, from the short circuit report data above, we can also see that the working time of the OCR Recloser L-01 works with a working time of 1.364 seconds and an outgoing PMT opening time of 2.7 seconds. This proves that the coordination of protective equipment at location 3 is good.

i. Analysis of OCR Relay Coordination Using Starview Graph at Location 3

To see how the coordination of the OCR relay installed on each protection equipment such as PMT incoming, PMT outgoing, and Recloser, I will give 2 fault simulations, namely short-circuit faults between phases and 3-phase short circuits, namely inter-phase faults with a fault current of 673 A and three-phase fault with a fault current of 779 A. In both disturbances the coordination of the relay above the working relay is the OCR relay on the Recloser L02, Recloser L01, and PMT outgoing side. For more details, see the Startview graph in Figure.

In figure 11 above, we can see that if there is a short circuit between phase of 673 A at location 3, the OCR relay on the Recloser-L02 side is working where the working time is 0.039 seocnds so that the safety coordination in the event of a short circuit between phases at location r is good because the Recloser that works to secure interference according to the work area of the Recloser L-02, the Recloser L-01 will secure if the Recloser L-02 is working with a working time of 1.03 seconds, the outgoing PMT will work with a working time of 1.72 seconds if the Recloser L-02 and L-01 failed to work.

j. Analysis of GFR Relay Coordination Using Startview Graph at Location 3

To see how the coordination of the GFR relay installed on each protection equipment such as PMT outgoing, and Recloser, I will simulate a single-phase short circuit to ground fault with a fault current of 388 A. In this fault the coordination of the relay above the working relay is the GFR relay on Recloser side for more details, look at the starview chart in Figure 12 below:

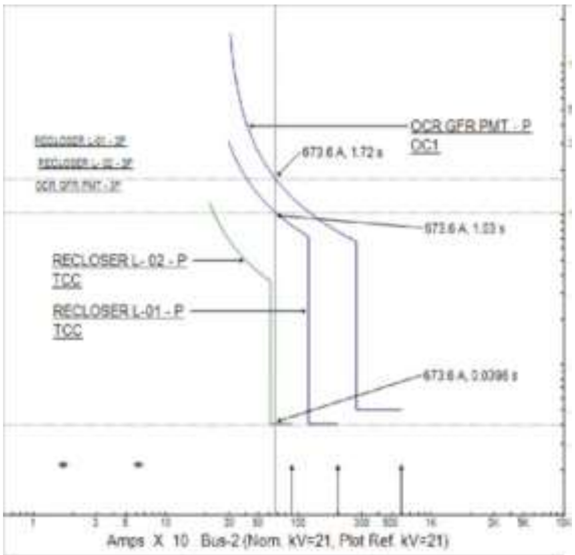


Figure 12. *Analysis of GFR Relay Coordination Using Startview Graph at Location 3*

In Figure 12 above, we can see that if there is a 1-phase short-circuit to ground fault of 388 A at location 3, the working is the GFR relay on the Recloser L-02 side where the working time is 0.0391 seconds, while for the Recloser L-01 1 working time. ,75 seconds if Recloser L02 fails to work and PMT Outgoing for a working time of 3.81 seconds if Recloser L-01 fails to work so that safety coordination in the event of a 1-phase short circuit to ground fault at location 3 is good because Recloser L-02 which works to secure interference according to the working area of Recloser L-02.

3.7 Comparison Evaluation of Calculation Results with Existing Data

From table 4, it can be seen the difference between the calculation results and existing data. The difference lies in the selection of Iset, Instant, and TMS on each relay. With the above results, a graph can be made to see the difference in the working time of each protection equipment.

Table 4. Comparison of Calculation Result Settings with Existing Data

No	Rele name	Relay Part	Existing Data	Calculati Data
1	OCR PMT outgoing	TMS	0.4	0.22
		ISET	360 A	280 A
		Instant	3600 A	2700 A
2	GFR PMT outgoing	TMS	0.6	0.628
		ISET	25 A	24 A
		Instant	2100 A	1500 A

3	OCR RecloserL01	TMS	0.2	0.175
		ISET	180 A	210 A
		Instant	1200 A	1000 A
4	GFR RecloserL01	TMS	0.25	0.345
		ISET	20 A	24 A
		Instant	700 A	600 A

No	Rele name	Relay Part	Existing Data	Calculation Data
5	OCR Recloser L-02	TMS	0.09	0.0675
		ISET	120 A	144 A
		Instant	680 A	600 A
6	GFR Recloser L-02	TMS	0.09	0.107
		ISET	20 A	24 A
		Instant	350 A	300 A

3.8 Comparative Evaluation of Coordination Results of Calculation OCR Settings with. Existing Data

Regarding the comparison of the coordination of the calculated OCR protection settings with Existing data, it can be seen that there is a difference in the PMT Outgoing (Existing) Curve with PMT Outgoing (Calculation Results) where the calculation results look more sensitive than the existing curve because the GAP working time between Recloser L-01 with PMT Outgoing is not too far away, so backing up if Recloser L-01 fails to work can be done quickly. Then the second difference lies in Iset both on Recloser L-01 and Recloser L-02. The results of the Iset calculation that I use are the latest peak load data retrieval data, while the existing data is the peak load data 6 months ago. From the two curves above, it can be concluded that both the existing data and the data from the calculation of the OCR settings are good because each protection equipment coordinates well in securing interference.

3.9 Comparative Evaluation of Coordination Results of GFR Calculation Settings with Existing Data

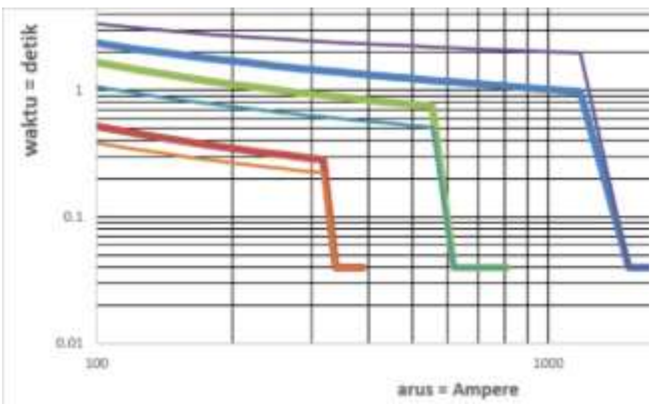


Figure 13. *Coordination Curve for GFR Protection Settings Calculation Results with Existing Data*

From Figure 13 above, related to the comparison of the calculated GFR protection settings coordination with Existing data, it can be seen that there is a difference in the PMT Outgoing (Existing) Curve with PMT Outgoing (Calculation Results) where the calculation results look more sensitive than the existing curve, this is because the GAP working time between the L-01 Recloser with PMT Outgoing is not too far away, so backing up if the L-01 Recloser fails can be done quickly. From the comparison of the two curves above, it can be concluded that both the existing data and the data from the calculation of the GFR setting are good because each protection equipment coordinates well in securing interference.

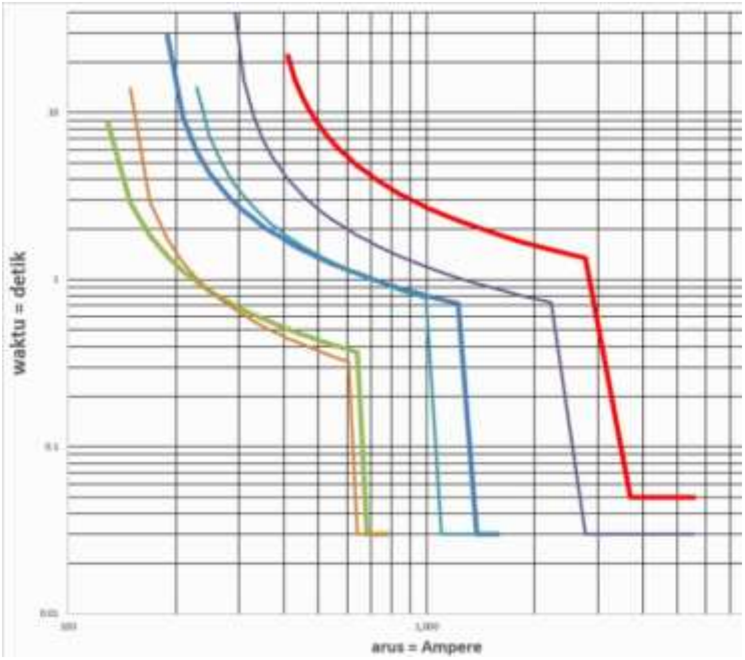


Figure 14. *Comparative Evaluation of Coordination Results of GFR Calculation Settings with Existing Data*

IV. Conclusion

From the discussion and calculations that have been carried out in previous chapters, the following conclusions can be drawn:

1. Based on the results of the analysis of manual calculations compared with calculations and simulations of the ETAP software, the value of the short-circuit fault current in the YB-02 feeder is that the closer the fault point is to the feeder base, the greater the short-circuit fault current is, and vice versa, the farther the fault point is from the base the feeder, the smaller the short-circuit fault current, both single-phase short-circuit current to ground, inter-phase short-circuit, and three-phase short-circuit.
2. Based on the results of the analysis of manual calculations compared with calculations and simulations of the ETAP software, the coordination of OCR and GFR relay protection in securing shortcircuit faults that occur has coordinated well. This is indicated by the graph of the OCR and GFR curves of each protection equipment (Recloser L-01, Recloser L02, and PMT Outgoing) that can coordinate well in securing interference according to their respective work zones.

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