ISSN: 2720-989X
JOURNAL OF ENERGY AND ELECTRICAL ENGINEERING

Coordination of Reclosers and Fuse Cut-Outs on 20 kV Medium Voltage Overhead Lines (SUTM) at the Eban Feeder of PT. PLN (Persero) ULP Kefamenanu

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[*submitted*: 02-07-2025 | *review*: 08-10-2025 | *published*: 31-10-2025]

ABSTRACT: *The Eban feeder is the longest feeders at PT. PLN (PERSERO) ULP Kefamenanu, with a medium-voltage overhead line length of 60.62 kms. In the distribution system, the Eban feeder is equipped with one Joongwon recloser on the medium-voltage network and 16 Fuse Cut Outs (branch points). This study aims to determine the coordination between the recloser and the Fuse Cut Outs (FCO) on the Eban feeder. The research method used is quantitative descriptive to identify the coordination settings of the recloser and FCO. The test data in this study include recloser settings, FCO ratings, transformer data, load data, CT data, and simulation using Etap 19.0.1. In the event of a short-circuit fault, the Nian recloser will operate first, with a breaking time of 0.521s.*

KEYWORDS: *Coordination, Recloser, Fuse Cut Out,* SUTM 20kV

I. INTRODUCTION

A distribution network is a channel or network that connects a large power source (substation) with consumers or electricity users, whether factories, industries, or households. This distribution system is useful for distributing electrical power from a large power source (bulk power source) to consumers. The electrical power distribution system includes all 20kV Medium Voltage Networks (MVN) and all 380/220 Volt Low Voltage Networks (LVN) up to the customer's KWh meter (Paembonan, 2021).

Currently, electricity consumption is increasing, so that in the distribution of electricity, there are often disruptions to the distribution system that a system with high reliability is required. System reliability is necessary to protect equipment from disturbances, reduce disturbance areas, and enhance the continuity of electricity supply. System reliability can be assessed through the coordination of protection systems that function effectively in distribution networks (Ulumudin, 2021). To support the creation of a reliable electrical system, good equipment is also required, starting from the required safety capacity rating, the required time settings, the number of devices used, and the placement of these devices. This is especially true for medium-voltage networks 20 kV where on the network this often occurs disturbances. (Wahyu, 2021)

II. RESEARCH METHOD

The method used in this quantitative descriptive research is a research approach used to describe and explain the situation being studied objectively using numbers, beginning with a literature study, which involves collecting and studying theorems that support the solution to the problem being studied. Data collection was then carried out by taking the required data on single line diagrams, channel lengths, customer data, disturbance data, and so on at PT.PLN (Persero) ULP Kefamenanu. From the data obtained, single line diagram modeling was then carried out using ETAP 19.0.1 software. This study also used the observation method to observe the condition of the Recloser and FCO safety systems on the Eban feeder.

A. DATA COLLECTION METHOD

1. Literature Study

Literature study is a method used to obtain information that supports the issues to be raised. Reading and reviewing journals helps the research process and reveals the strengths and weaknesses of previous studies, which can then be used as references in the research to be conducted.

2. Interview

Interviews are a data collection method that involves conducting direct question and answer sessions on issues related to Recloser and Fuse Cut Out coordination, with the aim of obtaining data that cannot be obtained by other means.

B. ETAP ANALYSIS FLOW

The analysis flow uses ETAP 19.0.1, which is:

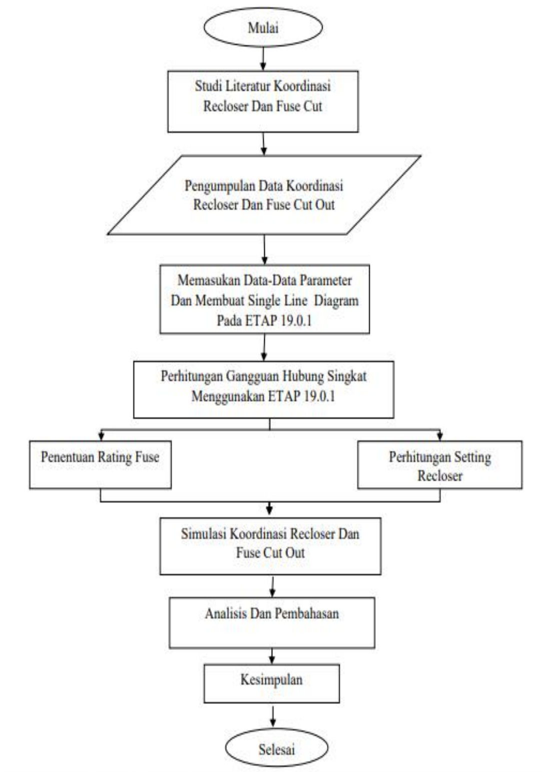
1. Data collection on the Eban feeder
2. Inputting parameters into ETAP 19.0.1
3. Running a short-circuit fault current simulation

C. DATA ANALYSIS

After conducting literature studies, interviews, and observations at the research site, the analysis techniques used in this study are:

1. Collecting single line diagram data and Eban feeder data
2. Calculating short-circuit fault currents
3. Coordinating Reclosers and Fuse Cut Outs as protection equipment in the Eban Feeder

D. RESEARCH FLOW CHART



E. SIMULATION OF THREE-PHASE SHORT-CIRCUIT FAULT CURRENT

This simulation was conducted to determine the magnitude of three-phase short-circuit fault current on Bus 186 using ETAP 19.0.1. Bus 186 was selected because it is the closest bus to the FCO and Recloser. The simulation of short-circuit fault current magnitude and fault points can be seen in Figure 1 below;

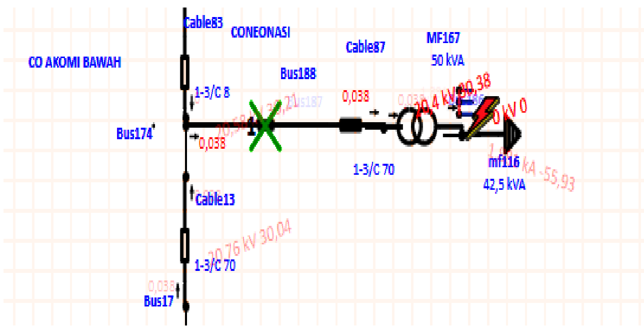


Fig. 1 Short-Circuit Fault on Bus 186

When a short circuit fault was induced on Bus 186, it was observed that the Fuse Cut Out operated, whereas the Recloser should have operated first. Relay settings were calculated using using short-circuit fault data and nominal current data. The short-circuit fault on Bus 186 is as follows:

Short-Circuit Summary Report

3-Phase, LG, LL, LLG Fault Currents

Bus		3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
Bus186	0.400	1.881	3.057	1.881	1.900	3.086	1.900	1.900	1.629	2.647	1.629	1.629	1.894	3.078	1.894	1.894

All fault currents are in rms kA. Current ip is calculated using Method C.

* LLG fault current is the larger of the two faulted line currents.

Fig. 2 Short Circuit Report

For the three-phase short circuit fault current of 1,881 kA, the single-phase to ground current of 1,900 kA, the two-phase current of 1,629 kA, and the two-phase to ground current of 1,894 kA.

F. RECLOSER CALCULATION

Reclosers require a time setting to extinguish short-circuit currents in the network. The recloser setting calculation is shown in fig. 3 as a reference containing the recloser specifications to be calculated using equation 2.3 for the short-circuit current setting (Ip), and at the fault distance closest to the recloser of 1.881 kA. The recloser current and operating time are calculated as follows:

$$Recloser\ Nian\ In = 22{,}6\ \text{A}$$

$$Ip = 1{,}05\ x\ In$$

$$\text{IP} = 1{,}05\ x\ 22{,}6$$

$$= 23{,}73\text{A}$$

$$\text{IFault} = 1881\ \text{A}$$

$$\text{t} = \frac{0.14}{\left(\frac{Ifault}{IP}\right)^{0.02} - 1}\ x\ 0.05$$

$$= \frac{0.14}{\left(\frac{1881}{23{,}73}\right)^{0.02} - 1}\ x\ 0.05$$

$$= \frac{0.14}{\quad}\ x\ 0.05$$

From the calculation results on the Nian Recloser, the next step is to input the t value into the recloser so hat it can be used as the time for recloser disconnection.

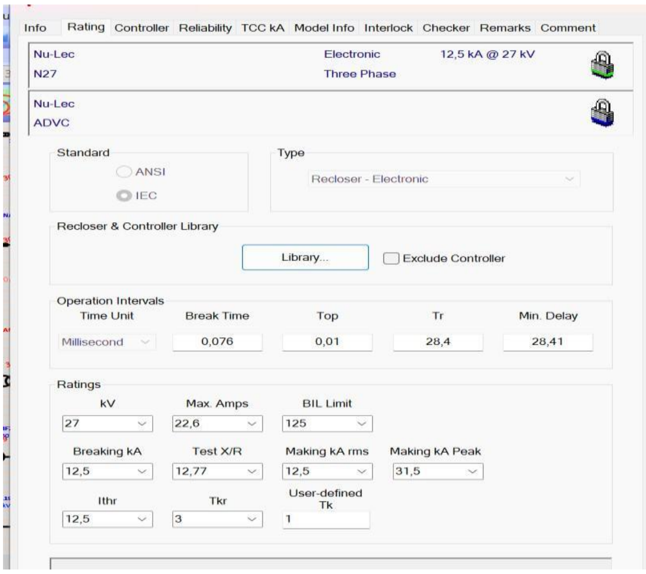


Fig. 3 Recloser Value Input

G. FUSE CUT OUT CALCULATION FOR EBAN FEEDER

The selection of FCOs in the distribution network must be able to withstand load currents and have the ability to interrupt short-circuit faults and protect conductors from faults. There are 16 FCOs installed on the Eban feeder distribution network, with ratings ranging from 2 A to 10 A. To calculate the FCO on the distribution network branch, use equation (2.5). One example of calculating the FCO rating on the Neonasi FCO branch with a transformer power capacity of 50 kVA is as follows: Ifuse can be calculated as follows:

$$\text{Ifuse} = \frac{Strafo}{V \times \sqrt{3}}$$

$$= \frac{50\ KVA}{20KV \times \sqrt{3}}$$

$$= \frac{50000}{20000 \times \sqrt{3}}$$

$$= 1.443\ \text{A}$$

Tbl. 1 FCO Nominal Current Calculation

The Neonasi FCO located at the MF167 substation has a maximum load value of 1.443 A, so the Neonasi FCO fuse capacity was selected to be 10 A. Next, input the Neonasi FCO data, which can be seen in Figure 4.4.

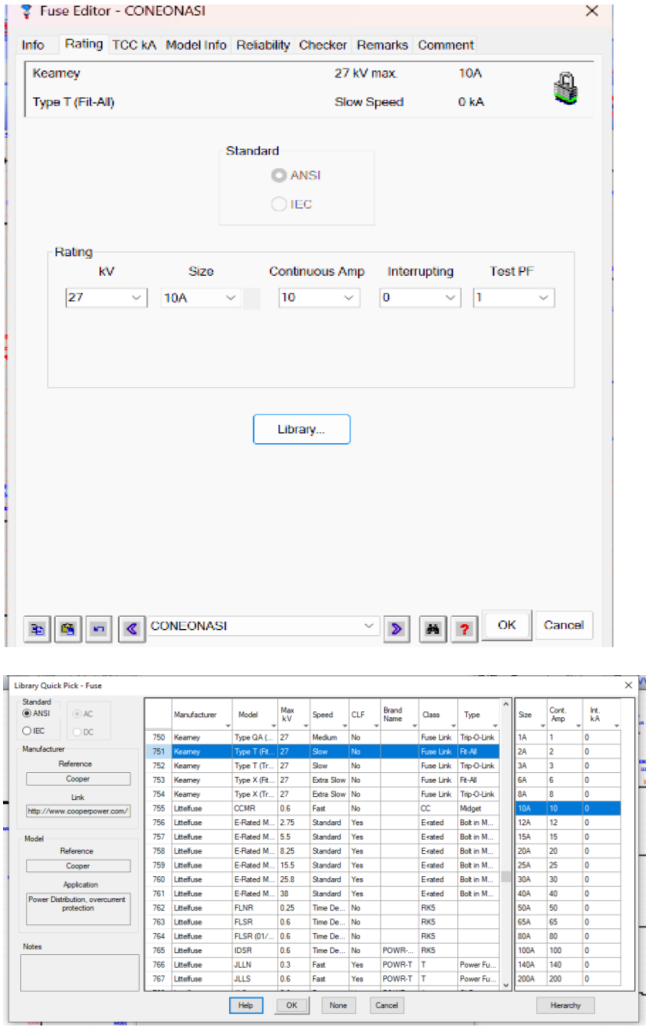


Fig. 4 Neonasi FCO Input

Based on the FCO data in the table above, a short circuit fault simulation was then performed on the Eban feeder using ETAP. The short circuit fault simulation was performed on the power system network model in the Eban feeder according to the existing load data and single line diagram. The simulation began with the selection of the area experiencing a short circuit, namely bus 186 located at the FCO Neonasi branch. This simulation aimed to determine the magnitude of the short circuit current on the Eban feeder. The types of faults simulated included three-phase short circuits, single-phase to ground, two-phase, and two-phase to ground.

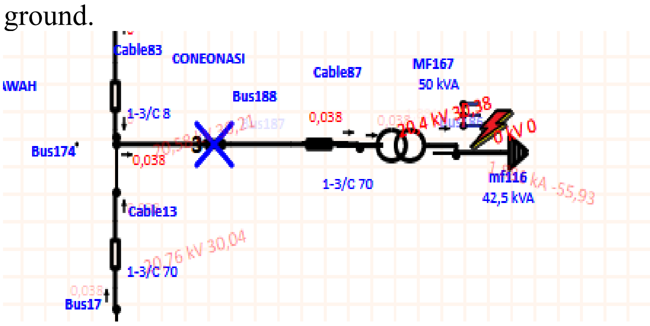


Fig. 5 Simulation of FCO Neonasi Operation at Bus 186

H. RECLOSER AND FUSE CUT-OUT COORDINATION

A simulation experiment was conducted to determine the coordination of Recloser and FCO protection on the Eban feeder. The simulation began with the selection of an area experiencing a short circuit disturbance, namely bus 186 located at the FCO Neonasi branch. This simulation aims to determine how the coordination of Recloser and FCO will occur on the Eban feeder.

a. Power Flow Simulation

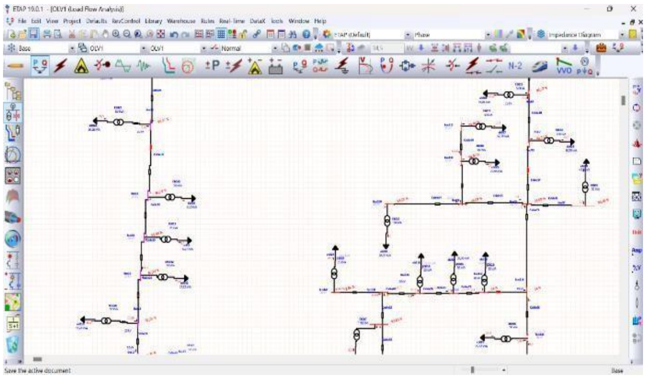


Fig. 6 Power Flow Simulation

Figure 6 shows that a power flow analysis was performed to determine the nominal current flowing to the recloser. The nominal current flowing is 22.6 A. This current is used to calculate the relay setting on the recloser in accordance with the nominal current flowing and a three-phase short circuit fault.

b. Non-Permanent Fault

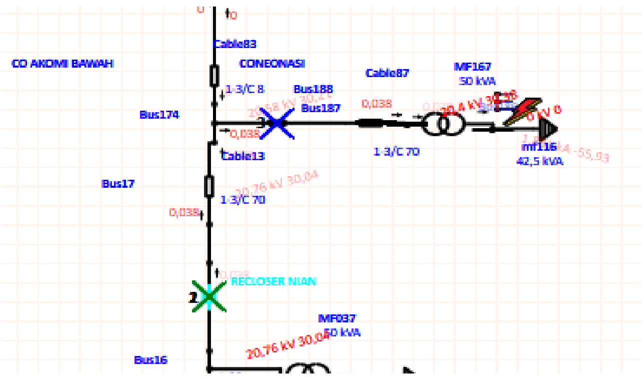


Fig. 7 Short Circuit Fault on Bus 186

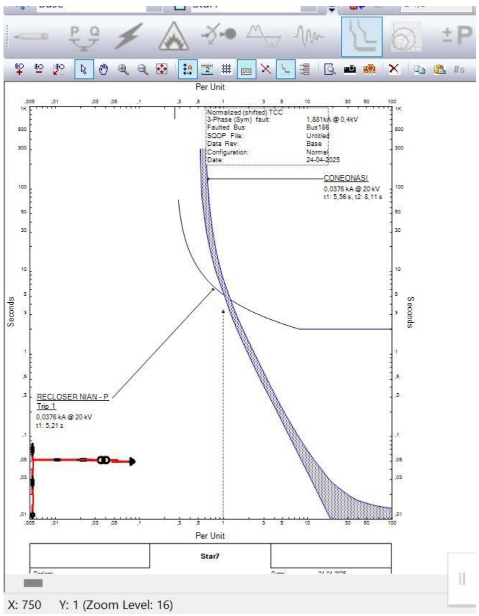


Fig. 8 Recloser and FCO Coordination Curve

After inputting the Recloser Nian and FCO Neonasi data, a coordination simulation between the two safety devices was carried out, as shown in Figure 4.8. This figure shows that when a disturbance occurs on Bus 186 as the point of disturbance, both safety devices will work with the coordinates that have been set. The short-circuit fault currents present on bus 186 after the simulation were as follows: a 3-phase short-circuit fault of 1.881 kA, a single-phase to ground fault of 1.900 kA, a two-phase fault of 1.629 kA, and a two-phase to ground fault of 1.894 kA. When there is a short-circuit fault current, the Nian Recloser will operate first. The Recloser's disconnection time is 0.0521 s. The Recloser has two operating modes, namely instantaneous disconnection and time delay disconnection. Both modes represent the performance of the recloser when a fault occurs. Non-permanent tripping operation is an operation that occurs when a fault occurs, where the recloser opens and closes the circuit immediately in a few short/fast cycles. A delay time of 0.076 s is required for a bus 186 recloser fault when a non-permanent fault occurs, so the tripping time is 0.0512 s with 2 tripping and followed by FCO at 0.05 s.

c. Permanent Fault

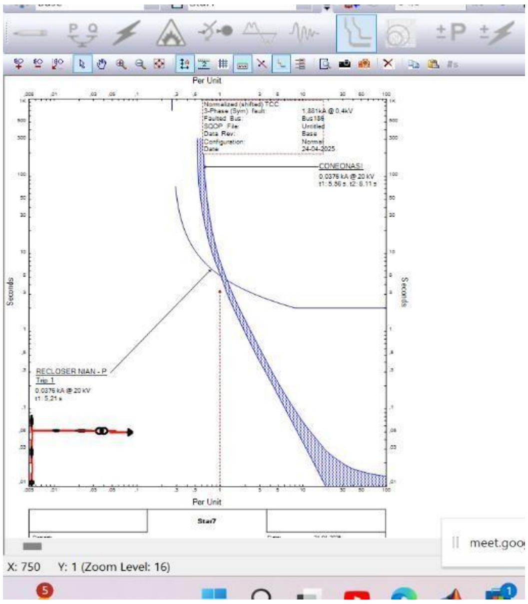


Fig. 9 Short Circuit Fault on Bus 186

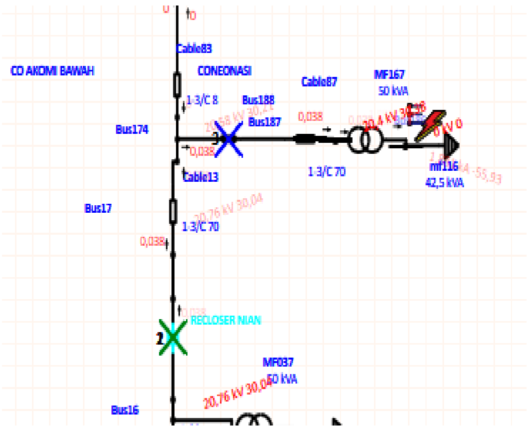


Fig. 10 Recloser and FCO Coordination Curve

From Figure 4.10, it can be seen that the recloser operates first with two strikes. The first strike occurs at 0.521 s, the second strike at 0.1 s, and the third strike at the Neonasi FCO at 0.05 s. The red arrow in the figure indicates a short circuit disturbance of 1.881 A or 1.881 kA. A trip occurs in the protection due to the current exceeding the maximum setting for short-circuit faults or the pickup current, which is 23.73 A. Therefore, when a fault occurs at 1.881 kA, the recloser and FCO detect the fault and trip.

The image above shows the coordination between the Recloser and FCO. The Recloser can detect permanent faults and perform a proper disconnection because it has a disconnection operation for permanent faults. Fuses cannot detect whether the excess current flowing is caused by a temporary or permanent fault. Due to the different disconnection operations between fuses and reclosers, coordination is performed such that during a temporary fault, the recloser operates to disconnect. For permanent faults, the recloser operates instantly; when it detects a fault, it immediately opens and closes again when the fault no longer occurs.

d. Operation of the Recloser's Remote Relay

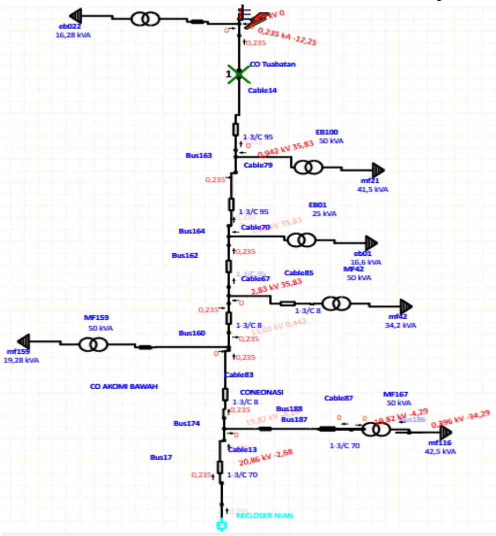


Fig 11 Remote Recloser Operation

As shown in Figure 4.11, several disturbances were applied to Bus 160 with transformer MF 159 at a distance of 2.5 km from the recloser, and disturbances were applied to Bus 162, 164, and 163. The relay worked properly. When a disturbance was applied to Bus 38 at a distance of 9.25 km from the recloser, the recloser did not work at this distance. The short-circuit fault current present on Bus 38 after sequential simulation is 0.235 kA for three phases and 0.135 kA for one phase. When a short-circuit fault current occurs, the Neonasi FCO will operate first. Meanwhile, the Recloser cannot operate at a long distance because the short-circuit fault current is significantly larger than the current and time relay settings on the recloser. Therefore, the FCO operates. The FCO trip times are t1 0.09 s and t2 0.027 s.

III. Conclusion

Based on the simulation results using ETAP 19.0 regarding short-circuit fault currents and coordination between the Recloser and FCO on the Eban feeder, the following conclusions can be drawn:

1. The largest short-circuit fault current is found at bus 1 with a 3-phase fault current of 28.868 kA, a 1-phase to ground fault of 1.056 kA, a 2-phase fault of 25.000 kA, and a 2-phase to ground fault of 25.001 kA. The smallest short-circuit fault current was found at bus 133 with a three-phase short-circuit fault of 0.143 kA, a single-phase to ground fault of 0.082 kA, a two-phase fault of 0.123 kA, and a two-phase phase to ground fault of 0.135 kA. The short-circuit fault currents found on bus 186

after successive simulations are a three-phase short-circuit fault of 1.881 kA, a single-phase to ground fault of 1.900 kA, a two-phase fault of 1.629 kA, and a two-phase to ground fault of 1.894 kA.

2. When performing a short circuit disturbance on Bus 186, it was observed that the Fuse Cut Out was operating, whereas the Recloser should have operated first. Relay settings were calculated using short circuit disturbance data and Nominal Current data. This allowed the Nian Recloser to coordinate with the Neonasi FCO. When a short circuit disturbance current occurs, the Nian Recloser will operate first. The Recloser's trip time is 0.521 seconds, while the Neonasi FCO will operate at 0.05 seconds. The relay settings on the Recloser are divided into two categories: instant and time delay. When a temporary disturbance occurs, the recloser will operate with the specified relay setting of 0.076 s, followed by the FCO disconnecting at 0.05 s. Then, when the disturbance is no longer detected, the recloser will automatically close again. When a permanent disturbance occurs, the recloser will operate instantly, disconnecting within 0 seconds, followed by the FCO within 0.05 seconds. When the disturbance is no longer detected, the recloser will automatically close again. The Nian recloser disconnects twice, followed by the Neonasi FCO.

IV. THANK YOU

Thank you to all those who have helped in the implementation of this research, especially to Mr. Frans J. Likadja, ST, MM, as the first supervisor. Dr. Almido H. Ginting, ST, M.Eng, as the second supervisor. Agustinus Sampeallo, ST, MT, as the examiner who has provided a lot of advice, input, and very constructive comments in guiding the author from the beginning to the end of this paper.

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