Power System Protection Coordination Studies at Gas Processing Plant B (GPPB), PETRONAS Gas Berhad (PGB), Paka

By

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DISSERTATION REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Siti Fathimah Bt Harun

ABSTRACT

Power system protection coordination is a study on protection for power system from any fault such as overcurrent, earthfaulth or any abnormal system operating condition that can cause failure to the systems component for example transformer, generator and transmission line. If any faults occur, the protection devices will recognize faults and initiate action to clear the fault from the system. In Gas Processing Plant B (GPPB), the protection system is an important part to take care but sometimes for some reason, the protection system is not work as what we want, therefore the studies on this project will be help the company to improve the current protection systems. This study is based on some characteristics in power system protection and develops the current power system protection coordination for Gas Processing Plant B (GPPB). With this new protection system coordination, the author hopes to help the company to improve the current protection systems.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

This study is intended to evaluate current power system protection coordination at Gas Processing Plant B (GPPB). Power system protection is a protection system used to protect important electrical component such as transformer, generator, bus structures, transmission line and even the loads that connected to the system from any fault, hazard such as short circuit or any abnormal system operating condition that would eventually cause failure of one or more system components. Therefore, the action is usually to isolate the portion of system experiencing the hazard so that the rest of system can operate normally as fast as possible. In doing so, the equipment will be safeguarded from further damage and more importantly from endangering human life. Having this criteria set and adhered to one can look at the second important objective that is to minimize interruptions. There is number of protective device available which are fuses, relays and circuit breakers.

The studies are basically on the characteristic of all protective devices and find in the suitable coordination that can be the best way to protect all power system components at Gas Processing Plant B (GPPB)

1.2 Problem Statement

Power system protection miscoordination had been observed to occur at GPPB during the tripping of the upstream protection when there was a fault at the downstream. A well coordinated protection system would allow the downstream protection to clear the fault discriminatively, hence reducing the load loss.

1.3 Objective of Study

1. To study the power system protection at Gas Processing Plant B, PETRONAS Gas Plant, Paka (GPPB, PGB).
2. To study on characteristic of each power system protection devices.
3. To improve current power system protection coordination at Gas Processing Plant B, PETRONAS Gas Berhad (GPPB, PGB).

1.4 Scope of Study

The studies are based on the electrical power system protection, characteristics of protection devices such as fuses, relays and circuit breaker, overcurrent and earthfault relay coordination and setting. Also this project will cover studies on coordination of overcurrent relays, differential relaying, and restricted earth fault protection.

Other than that, this project is mostly deal with ERACS software to get the best coordination of overcurrent setting and earthfault setting for power system protection in Gas Processing Plant (GPPB). The author will be exposing to the usage of the features in this new software through out this studies.

CHAPTER 2

LITERATURE REVIEW

Main purpose of distribution protection and electrical protective devices is to isolate the faulted component from the healthy parts as fast as possible. In doing so, the equipment will be safeguarded from further damage and more importantly from endangering human life. Also it is important to ensure that the distribution network can operate with preset requirement for the safety of public, staff and overall network including individual equipment. Having these criteria set then one can look at the second important objective, that is, to minimize interruptions or the cost of non-distributed energy.

2.1 Basic Component in Distribution Network

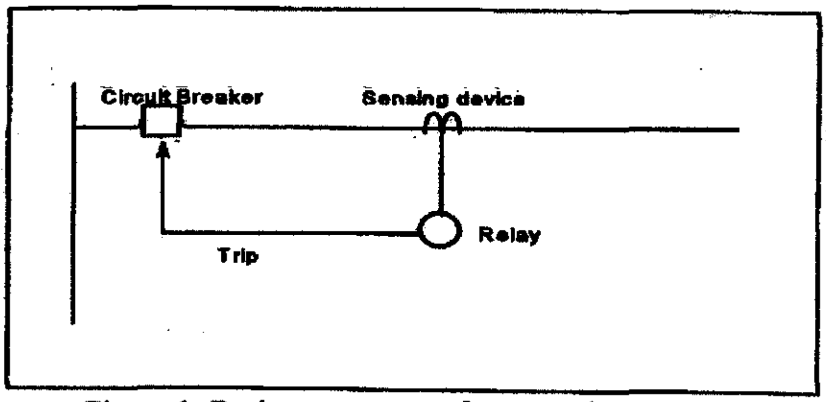


Figure 1: Basic component of a protective system

There are three basic components in distribution network as show in Figure 1 which are:

a) Sensing device
b) Relay
c) Circuit Breaker

When the fault occur along the network, the nearest sensing device will detect the fault in term of changes in measurement of basic electricity components which are current, voltage, or frequency. The measured quantity then sent to other basic component in distribution network which is relay. Relay act as decision maker for the network whether to isolate the faulted network or not. The decision is depending on the relay setting magnitude of the selected measured quantity. If measured quantity exceed relay setting then the relay will make the circuit breaker to trip therefore the faulted path will be isolated.

When designing, we have to make sure that the protection system is selective, sensitive, stable, fast and reliable.

a) Selective - Relay systems should only trip as much of the system as necessary to de-energize distressed components.[5]

b) Sensitive - Sensitive enough to operate under minimum fault condition.[1]

c) Stable - Stable and remain inoperative under certain specified conditions such as transmission system disturbance, through faults, transients, etc.[1]

d) Fast - Fast operation in order to clear the fault from the system thus to minimize damage to the affected components.[1]

e) Reliable - The protective equipment should not fail to operate in the events of faults in the protected zone. It may be necessary to provide backup protection to cover the failure of the main protection.[1]

2.1.1 Sensing Device

First component in protection system is sensing device. Usually use as sensing devices are current transformer and voltage transformer. Both use to facilitate the changes in current or voltage within some range.

2.1.1.1 Current Transformer

A current transformer as shown in Figure 2 comprises of two windings. The primary winding is connected in series with the main circuit. In most cases, the primary winding is part of the main circuit. The secondary winding comprises of several turns of wire wrap around an iron core. This provides ampere-turns relationship:

$$N_p I_p = N_s I_s$$

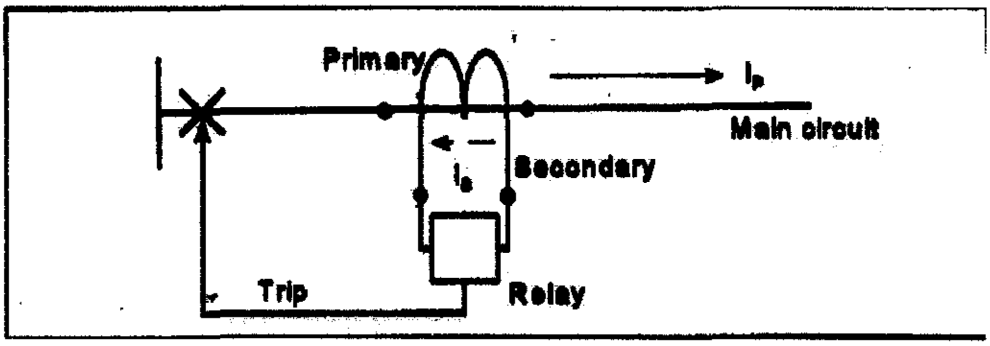


Figure 2: Connection current transformer to the network

Where N_p and N_s are the number of primary and secondary turns respectively. The idea is to provide large number of turns on the secondary to obtain small quantity of current that replicates the primary current. Current transformer ratio is defined as N_p/N_s (example 300/5 A). [4]

2.1.1.2 Voltage Transformer

This device (VT) is use for measurement, directional protection (conventional or reverse power relays) and undervoltage/overvoltage protection. The primary of the VT is connected directly to the power circuit between phase and ground as Figure 3. [4]

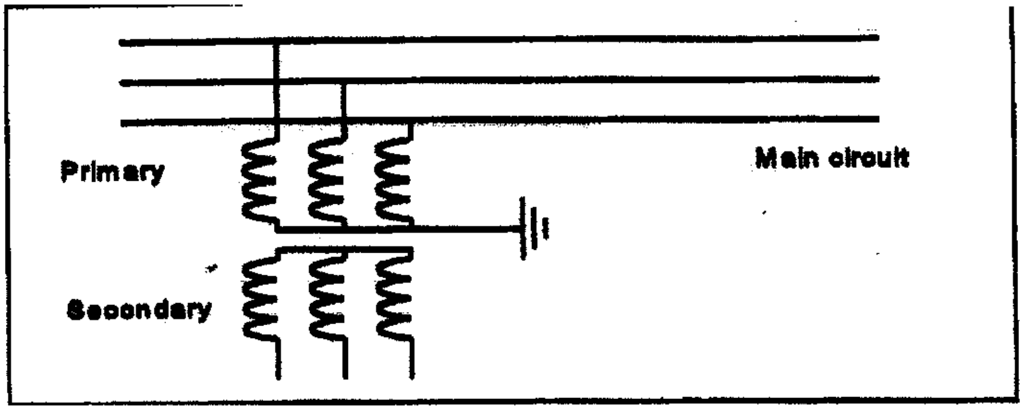


Figure 3: Connection of voltage transformer

2.1.2 Relay

Second component in protection system is relay. It usually installed with current transformers (CT) for current measurement. The current measured by the CT is proportional to the circuit current. When the current exceed a preset value, the relay will operate at a time depending on the characteristic of the relay. The basic function of the relay is thus to sense the presence of signal (circuit current) and activate an action that normally actuates the operation of switchgear if such a signal surpassed a certain set value. [4]

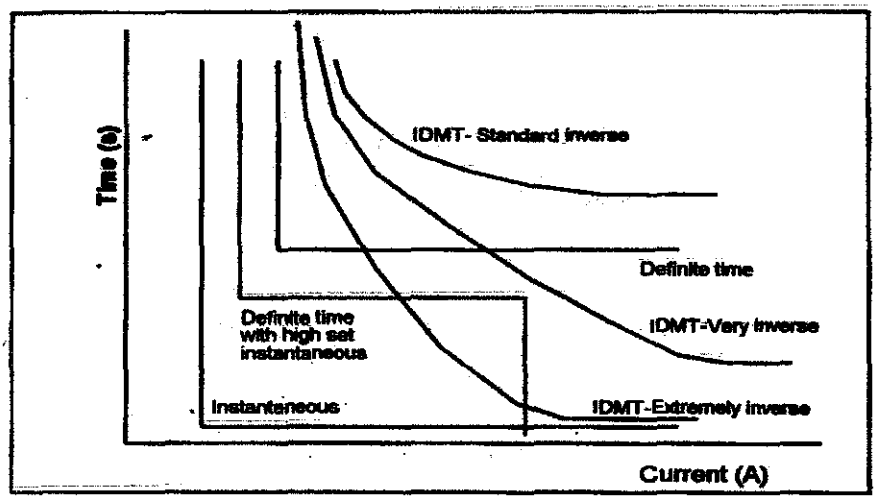


Figure 4: Graph time-current characteristic for different relays

Relays are normally classified into the time/current characteristics as shown in graph above:

- Instantaneous
- Definite-Time
- Inverse Definite Minimum Time (IDMT)

- Standard Inverse: $t = \dfrac{0.14}{(I^{0.02}-1)} \times$ time setting secs

- Extremely Inverse: $t = \dfrac{0.14}{(I^{2}-1)} \times$ time setting secs

- Very Inverse: $t = \dfrac{0.14}{(I-1)} \times$ time setting secs

Throughout this project, the author use standard inverse IDMT relay characteristic which have the equation:

$$t = \frac{0.14 \times \text{TMS}}{\left(\dfrac{\text{FAULT CURRENT}}{\text{SETTING CURRENT}}\right)^{0.02} - 1}$$

2.1.3 Circuit Breaker

Last component in protection system is circuit breaker. It is use to break the connection between the faulted path and healthy path. There are many types of circuit breaker, for example Molded Case Circuit Breaker (MCCB), Air circuit Breaker (ACB), Gas Circuit Breaker (GCB). Selection of circuit breaker to use is depending on the voltage that the system works with. For circuit breaker use at high voltage, we can find it inside switchgear.

Figure 5: Vacuum circuit breaker use at high voltage

2.2 Types of distribution protection

There are various types of protection that can be considered in any distribution network.

2.2.1 Non-unit Protection

Non-unit protection is a time/current graded system where protective systems in successive zones are coordinated to operate at different times. When a fault occurs, a number of relays will respond and only those closest to the fault complete the tripping operation leaving the remaining relays reset. [1]

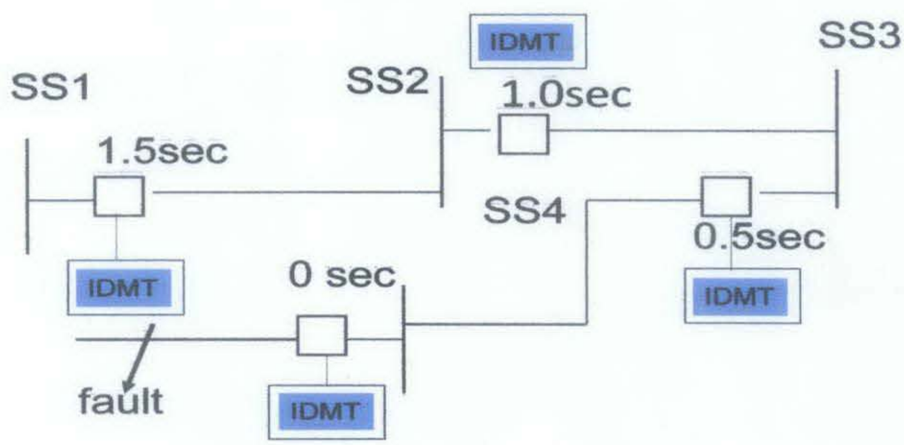


Figure 6: Non-unit Protection

2.2.2 Unit Protection

A unit protection is a protection system in which the protected zone can be clearly identified by means of CT boundaries. Such protection does not respond to through fault (out zone fault). It responds to only internal faults or faults inside the protected zone. As shown in Figure 7. [1]

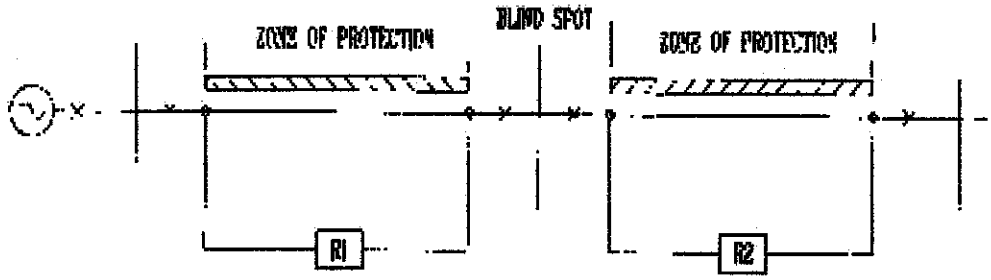


Figure 7: Unit Protection

2.2.3 Overcurrent and Earthfault Protection

Overcurrent and Earthfault protection is used to protect feeders, transformers, motors, capacitors and other equipment. The protection devices used are either fuses or relays. Usually we used the combination connection between overcurrent and earthfault (OCEF) relays like shows below. [4]

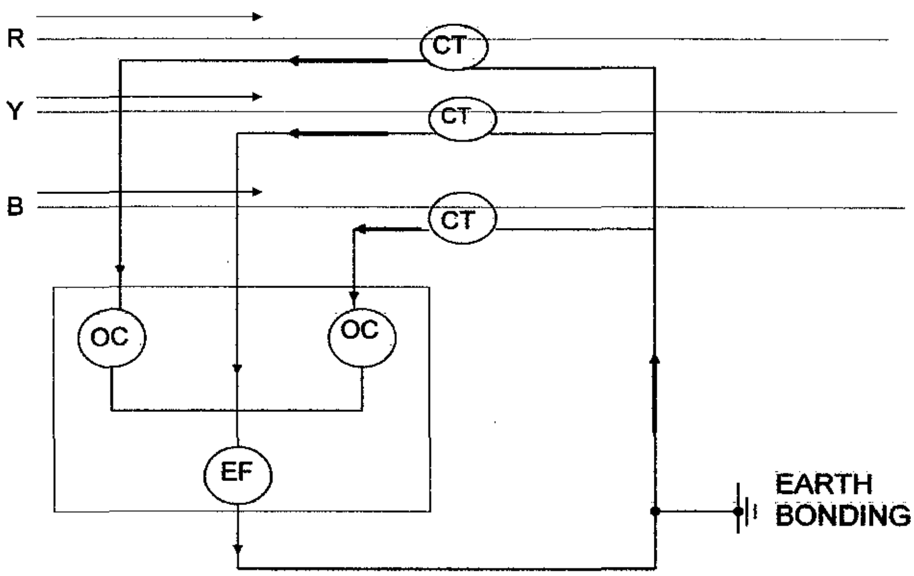


Figure 8: Example connection of Overcurrent and Earthfault (OCEF) relays to the three phase network

2.2.3.1 Overcurrent Protection

The objective for overcurrent protection is to detect fault affecting one or two phase. Overcurrent protection involve inclusion of suitable device which is overcurrent relay in each phase and is energized by current transformer

Magnitude of an interphase fault current depends on the impedances of the system. Usually the phase fault current is larger. When calculating grading margin for overcurrent relay, we use three phase fault current and the maximum load or current carrying capacity of the cable/line/transformer will determine the setting current.

2.2.3.2 Earthfault Protection

Earthfault protection is required to have a high sensitivity to earth faults. Earthfault setting are often required to be lower than system rating. When calculating grading margin for earthfault relay, we use single phase fault current. Normally a setting of 10%-20% from current transformer rating is used as earthfault setting current.

2.3 Protection Relay Coordination

2.3.1 Load Flow Analysis

Load flow analysis must be done first before doing the grading margin for protection relay coordination. Load flow analysis were run to confirm that the busses, switchboard, Motor Control Centre (MCC), transformer and feeder cables would operate within their ratings, and also to determine the real and reactive power, bus voltage and load level at all busses.

2.3.2 Fault Calculation

Next step we must know the current fault at every busses either three phase current fault or single phase current fault. Fault calculation is fundamental to protective relay setting and coordination. Knowledge of maximum 3-phase fault MVA at any point in the system would enable one to initially set the operating time of the relays to ensure that it is within the withstand capability of the equipment.

With knowing three phase fault, then coordination exercise can be performed for overcurrent setting since 3-phase fault current is the highest fault current in the system while single-phase to ground fault value is very important to coordinate earthfault setting as this is the highest earthfault current in the system. The criteria to choose 3-phase fault current for overcurrent setting and single-phase to ground fault current for earthfault setting is based on normal Inverse Definite Minimum Time (IDMT) relay characteristics.

2.3.3 Protection Coordination

2.3.3.1 Grading margin criteria

Grading margin between adjacent relays is determined by several factors:

- Circuit Breaker Time
- Relay overshoot
- Instrument Errors

Two methods of determining grading margins:

- Fixed margin

  Time margin is estimate as follows:

- Circuit Breaker Time	- 0.10sec
- Relay Overshoot	- 0.04sec
- Relay Error	- 0.10sec
- Instrument Error	- 0.10sec
- Safety Margin	- 0.10sec
Total Margin	- 0.44sec

The margin could range between 0.3-0.5 sec. In practice for this project, the author use margin 0.4 sec.

2.3.3.2 Plug Setting (PS)

Plug setting will set the minimum operating current. Usually it is in electromechanical/electronic relay or in numerical relay.

2.3.3.3 Time Multiplier Setting (TMS)

It gives operating time scale for maximum disc movement.

2.3.3.4 Relay Setting Calculation Steps

- For Transformer - the max operating time at LV side must considering transformer damage curve. For this network, transformer damage curve considered as 1.6 sec.
- No margin required within feeder and 0.4 sec margin between feeder
- For OC set PS = current carrying capacity and adjust TMS to get required margin
- For EF set PS = 20% of ct ratio and adjust TMS to get required margin

For this project, all of the calculation mainly calculated by ERACS software because it is much faster to perform calculation and without arithmetic error and also the system that has been setup for computer calculation could be modified easily and calculation can be repeated.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

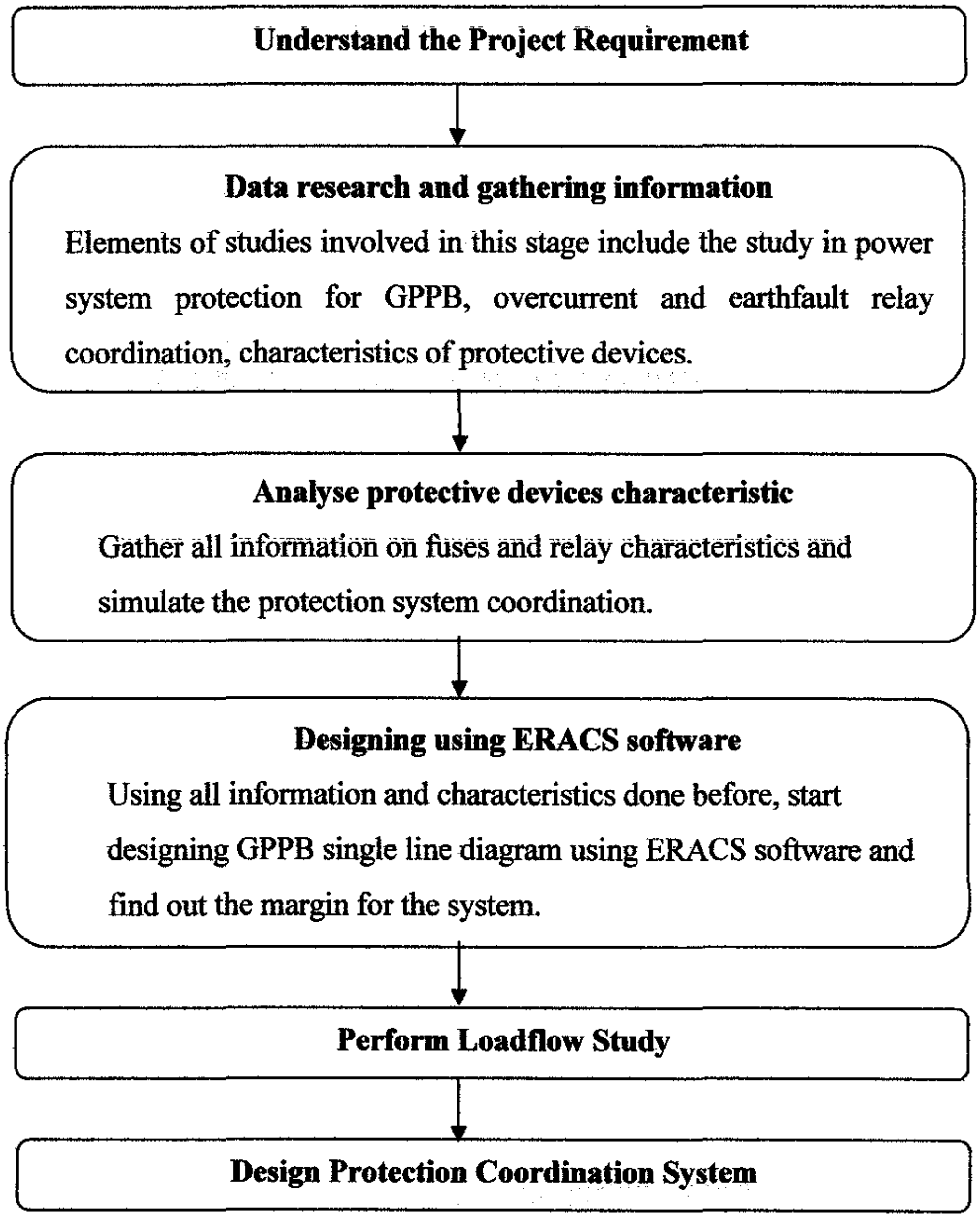


Figure 9: Flow chart of project

3.2 Tools and Equipment

- ERACS software

  - ERACS software is a power system software used to calculate the load flow study, fault analysis and calculate the protection coordination of the network
  - Complete design the network for high voltage level.
  - Complete design the grading margin for one path of the network.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Result

The author design GPPB network for high voltage level up to 11kV voltage motor using ERACS software. The network as below:

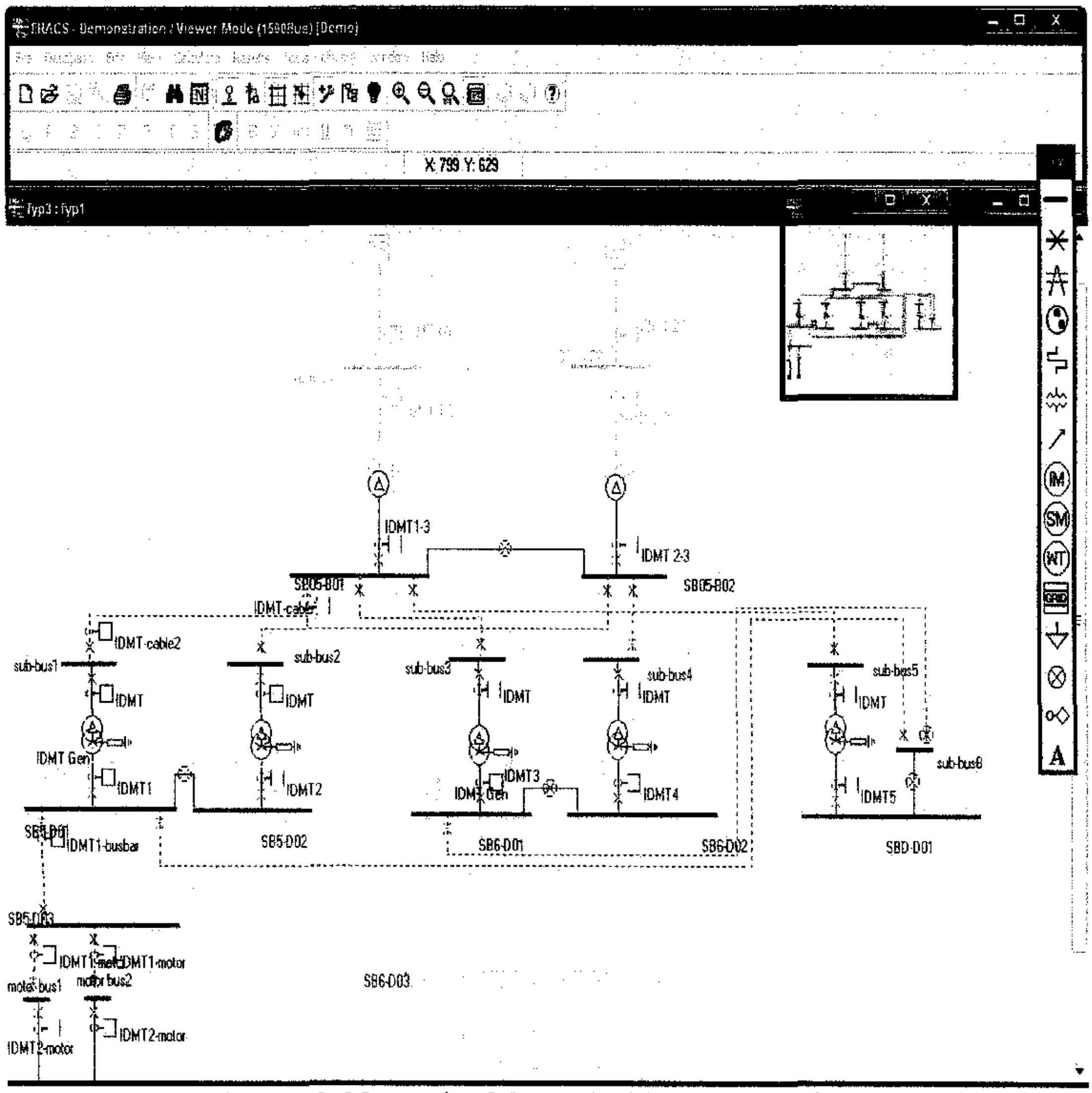


Figure 10: Network of GPPB inside ERACs software

Result simulation for the first path. It is including Grid 1 up to the 6.6kV motor (PM5-0202A), the result for Plug Setting and Time Multiplier as the show in Table 1.

Table 1: PS and TMS Overcurrent values for first path

Relay	Plug setting	Time Multiplier	Description
IDMT 1-1	0.4	0.2	-
IDMT 1-2	0.4	0.2	No margin
IDMT 1-3	0.75	0.25	Remaining time < 0.2 sec
IDMT cable 1	0.75	0.175	Margin 0.4 sec
IDMT cable 2	0.75	0.175	No margin
IDMT	0.75	0.175	No margin
IDMT 1	0.70	0.25	Remaining time < 0.2 sec
IDMT Busbar	0.85	0.125	Margin 0.4
IDMT 1 motor	0.85	0.05	Margin 0.4
IDMT 2 motor	0.85	0.05	No margin

Table 2: PS and TMS Earthfault values for first path

Relay	Plug setting	Time Multiplier	Description
IDMT 1-1	0.05	0.05	-
IDMT 1-2	0.05	0.05	No margin
IDMT 1-3	0.15	0.05	Remaining time < 0.2 sec
IDMT cable 1	0.15	0.10	Margin 0.4 sec
IDMT cable 2	0.15	0.10	No margin
IDMT	0.15	0.10	No margin
IDMT 1	0.15	0.25	Remaining time < 0.2 sec
IDMT Busbar	0.20	0.20	Margin 0.4
IDMT 1 motor	0.20	0.05	Margin 0.4
IDMT 2 motor	0.20	0.05	No margin

4.2 Discussion

4.2.1 Relay Coordination for Overcurrent Protection

Start grading margin with calculation of the relay's CT ratio usage hence getting the fix Plug setting (PS) of the relay that will be used through out the project.

4.2.1.1 Full load current at 132 kV

$$I_{FL} = \frac{MVA}{\sqrt{3} \times VLL} = \frac{50\ MVA}{\sqrt{3} \times 132kV} = \mathbf{218.69A}$$

MVA value is the maximum capacity transformer can carry. In this case the maximum capacity is 50MVA for 132/6.6 kV transformer.

$$PS = \frac{Full\ load\ current}{CT\ ratio} = \frac{218.69}{600} = 0.3645$$

- ❖ Choose nearest PS available = 0.4

With PS at 0.4, the minimum available current that relay can carry is

$$I_{Min} = 0.4 \times CT\ Ratio = 0.4 \times 600 = \mathbf{240A}$$

Therefore, minimum current that is allowable to flow through the 132kV relay is 240A.

4.2.1.2 Full load current at 33 kV

$$I_{FL} = \frac{MVA}{\sqrt{3} \times VLL} = \frac{50\ MVA}{\sqrt{3} \times 33kV} = \mathbf{874.77A}$$

$$PS = \frac{Full\ load\ current}{CT\ ratio} = \frac{874.77}{1200} = 0.729$$

- ❖ Choose nearest PS available = 0.75

With PS at 0.75, the minimum available current that relay can carry is

$$I_{Min} = 0.75 \times \text{CT Ratio} = 0.75 \times 1200 = \mathbf{900A}$$

Therefore, minimum current that is allowable to flow through the 33kV relay is 900A.

The same steps use to calculate other equipments rating such as at the second transformer 33/6.6 kV transformer and motor rating. The result for the first path for overcurrent protection as table below:

Table 3: List of Plug Setting for Overcurrent Protection

Relay	CT Ratio	Full load current	Plug Setting (PS)	Allowable current
IDMT 1-1	600/1	218.69	0.4	240
IDMT 1-2	600/1	218.69	0.4	240
IDMT 1-3	1200/1	874.77	0.75	900
IDMT cable 1	600/1	437.39	0.75	450
IDMT cable 2	600/1	437.39	0.75	450
IDMT	600/1	437.39	0.75	450
IDMT 1	3000/1	2091.85	0.70	2100
IDMT Busbar	1250/1	1049.73	0.85	1062.50
IDMT 1 motor	1250/1	1049.73	0.85	1062.50
IDMT 2 motor	1250/1	1049.73	0.85	1062.50

4.2.2 Grading Margin for Overcurrent Protection

4.2.2.1 IDMT 1-2

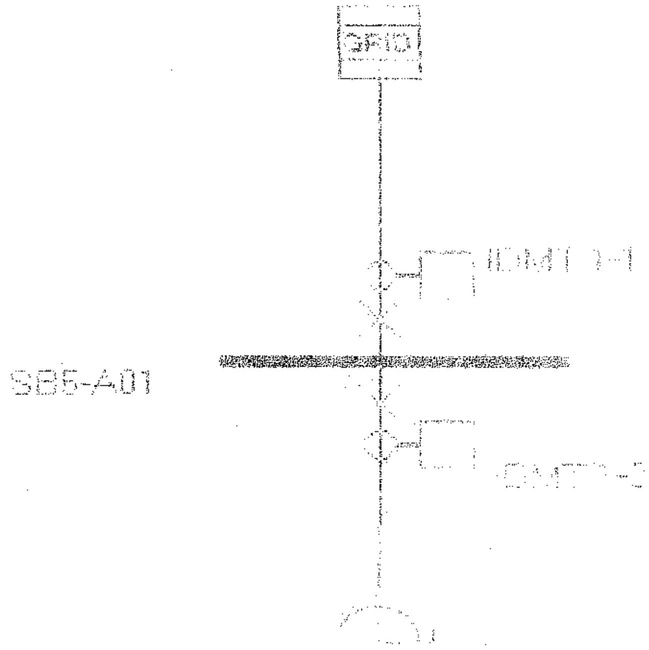


Figure 11: Location of IDMT 1-1 and IDMT 1-2

Start grading the network from grid 1 for IDMT 1-1 for overcurrent relay protection. The grid 1 is from PAKA132_M1 substation which has the characteristic as below:

Table 4: Fault current and impedance for grid 1

Characteristic	Value
3-phase current fault (A)	22 010.10
1-phase current fault (A)	25 757.50
Positive impedance	0.254 + j3.453
Negative impedance	0.663 + j3.774
Zero impedance	0.146 + j1.585

Given value for TMS and PS for overcurrent IDMT 1-1 relay as:

Overcurrent setting: PS = 0.4

TMS = 0.2

Using the value given, we grade IDMT 1-2 relay which is the relay after IDMT 1-1. The purpose is to find its Time Multiplier Setting (TMS). There is no margin required between this two relay because there is no other feeder connected to relay IDMT 1-1 and we can consider it as relay in the same feeder. Therefore we get the same graph characteristic for relay IDMT 1-1 and IDMT 1-2 as shown in Figure 12.

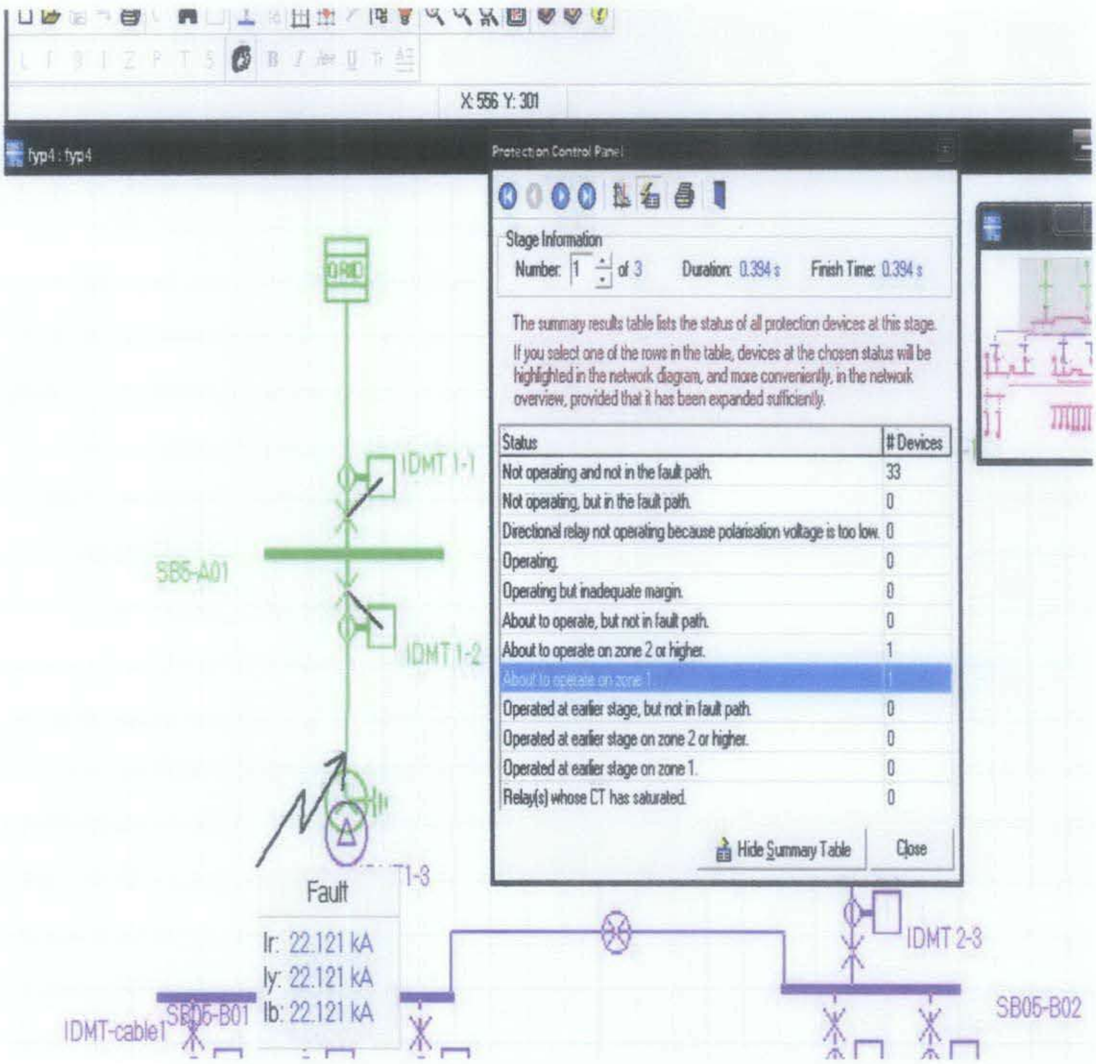


Figure 12: Result of Coordination Protection IDMT 1-2

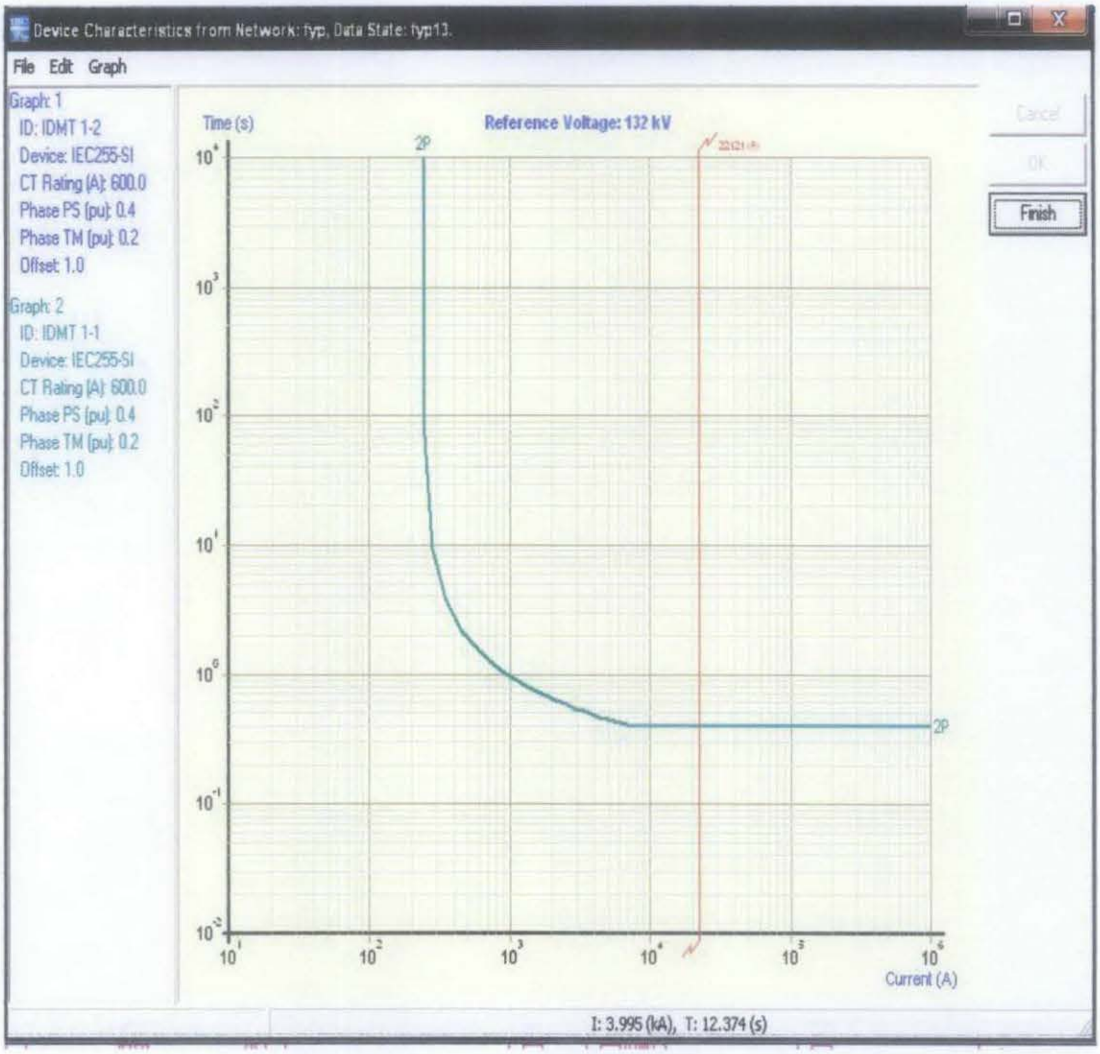


Figure 13: Graph for IDMT 1-1 and IDMT 1-2

After grading, value for IDMT 1-2 relay are:

Overcurrent setting: PS = 0.4

TMS = 0.2

4.2.2.2 IDMT 1-3

For the second grading which is IDMT 1-3 relay, this relay is located at low voltage transformer.

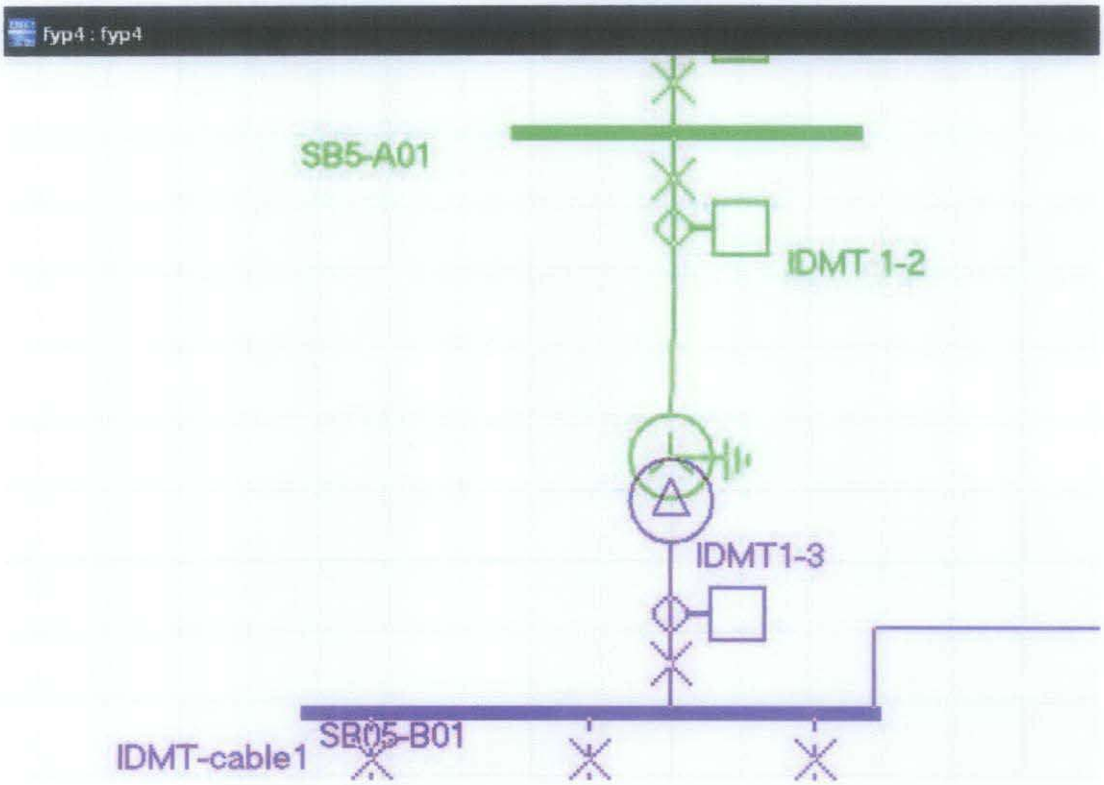


Figure 14: Location of IDMT 1-3

Note that, we have to considered transformer damage curve in order to design this relay. There are two characteristics that we have looked for to set Relay's TMS:

1. Relay operating time must not exceed 1.6 sec which means the TMS value can be increase until its operating time for relay is 1.6 sec

2. The remaining time must be less than 0.2 sec (since we only consider circuit breaker time and safety margin which total up given 0.2 sec)

But for this system, we use the second characteristic since the value for operating time is too small so we have to consider its remaining time must not be less than 0.2 sec.

Therefore, value for IDMT 1-3 relay is:

Overcurrent setting: PS = 0.75

TMS = 0.25

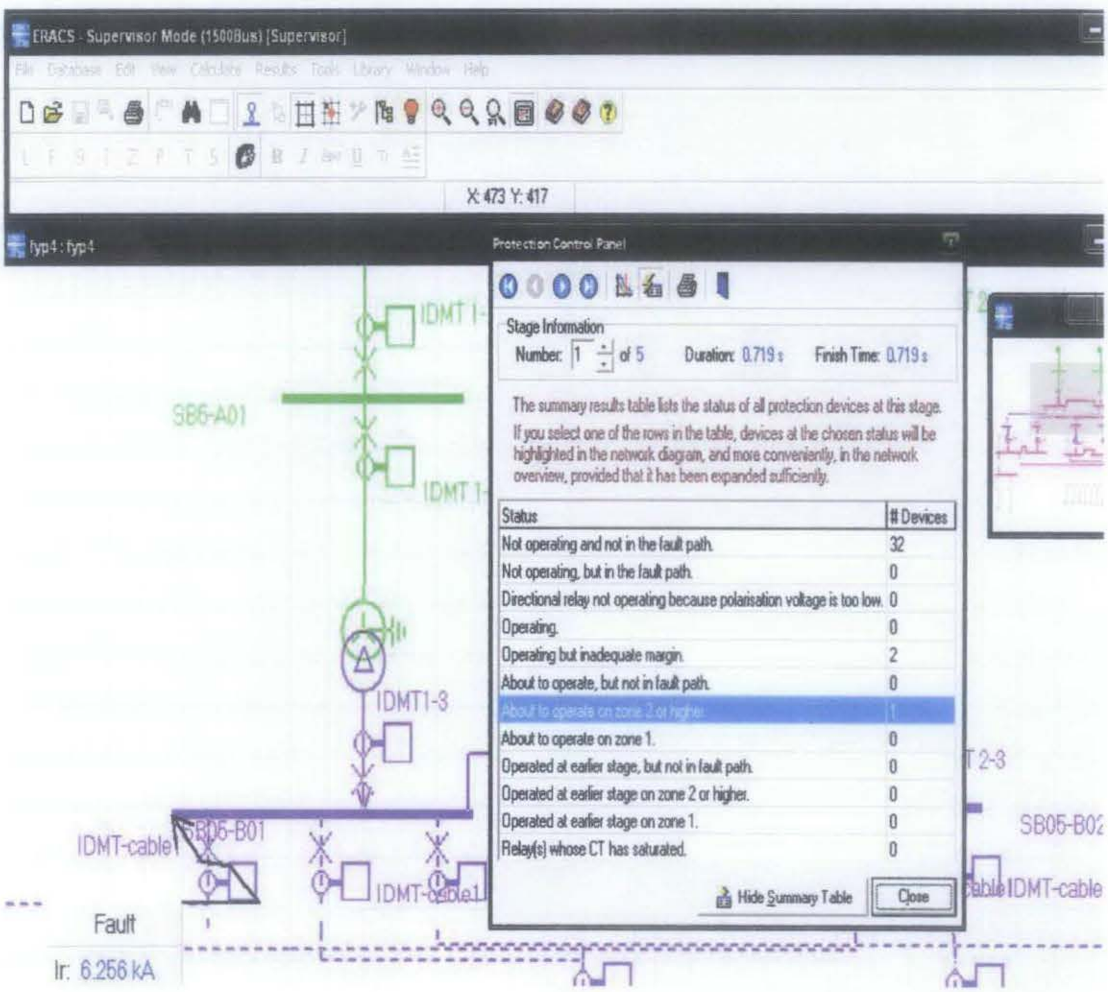


Figure 15: Result of Coordination Protection IDMT 1-3

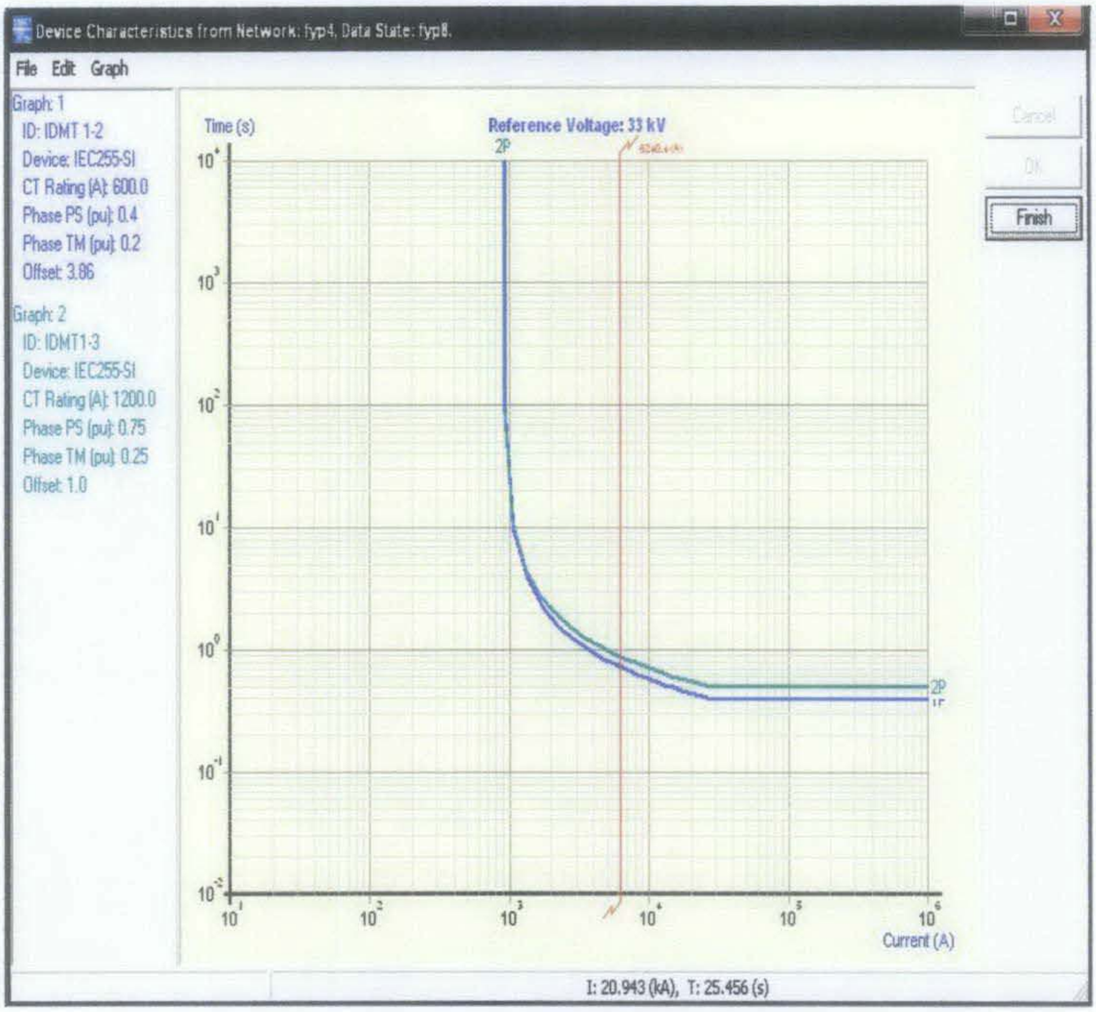


Figure 16: Graph for IDMT1-2 and IDMT 1-3

From the graph we can see that the graph for IDMT 1-3 cross the graph for IDMT 1-2. We accept this criteria because in real practice both relay IDMT 1-2 and IDMT1-3 is actually operating at the same time when fault occur at bus SB6-B01 because we already consider the circuit breaker time and safety margin for the breaker which is less than 0.2 sec. In this case it is around 0.166.

Figure 17: Result for IDMT1-2 and IDMT 1-3

4.2.2.3 IDMT cable 1, IDMT cable 1-2 and IDMT

Margin for this IDMT-cable1 with IDMT 1-3 is 0.4 sec since this relay is in different feeder. But no margin required for next three relays which are IDMT cable 1, IDMT-cable2 and IDMT because these relays is in the same feeder.

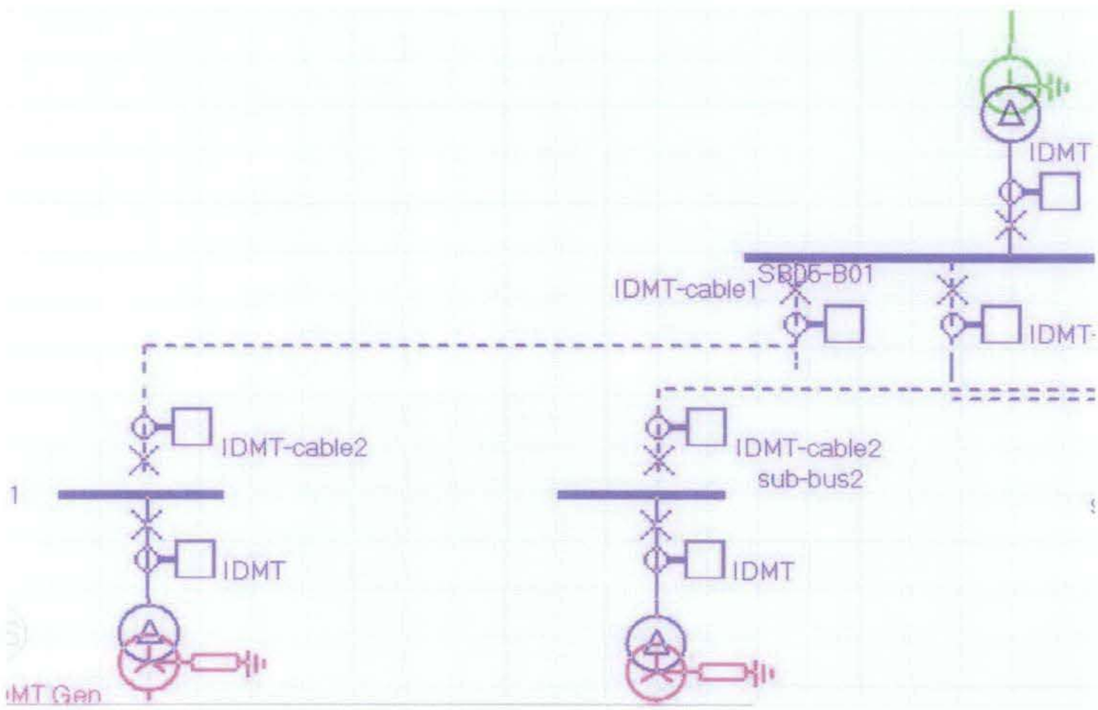


Figure 18: Location of IDMT cable 1, IDMT cable 1-2 and IDMT

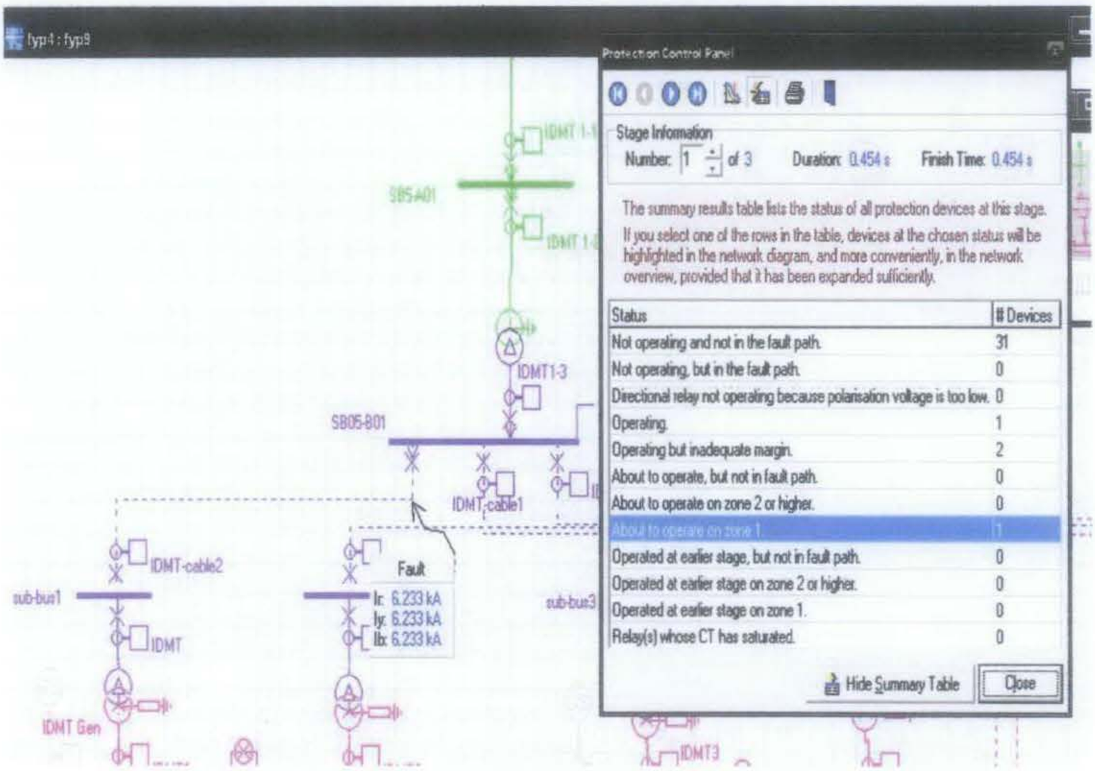


Figure 19: Result of Protection coordination IDMT-cable 1, and IDMT 1-3

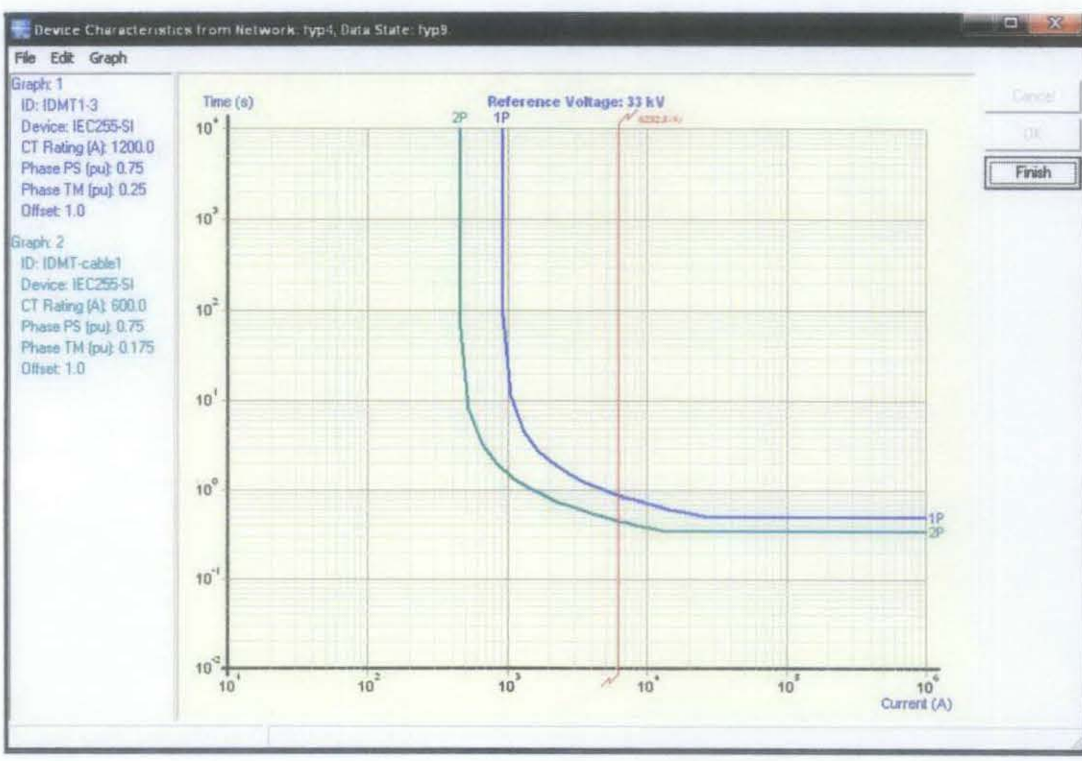


Figure 20: Graph for IDMT 1-3 and IDMT-cable1

The 0.4 margin required for IDMT 1-3 and IDMT-cable1 result the graph characteristic as Figure 20. The different at the fault current line for both of the graph is 0.4 sec.

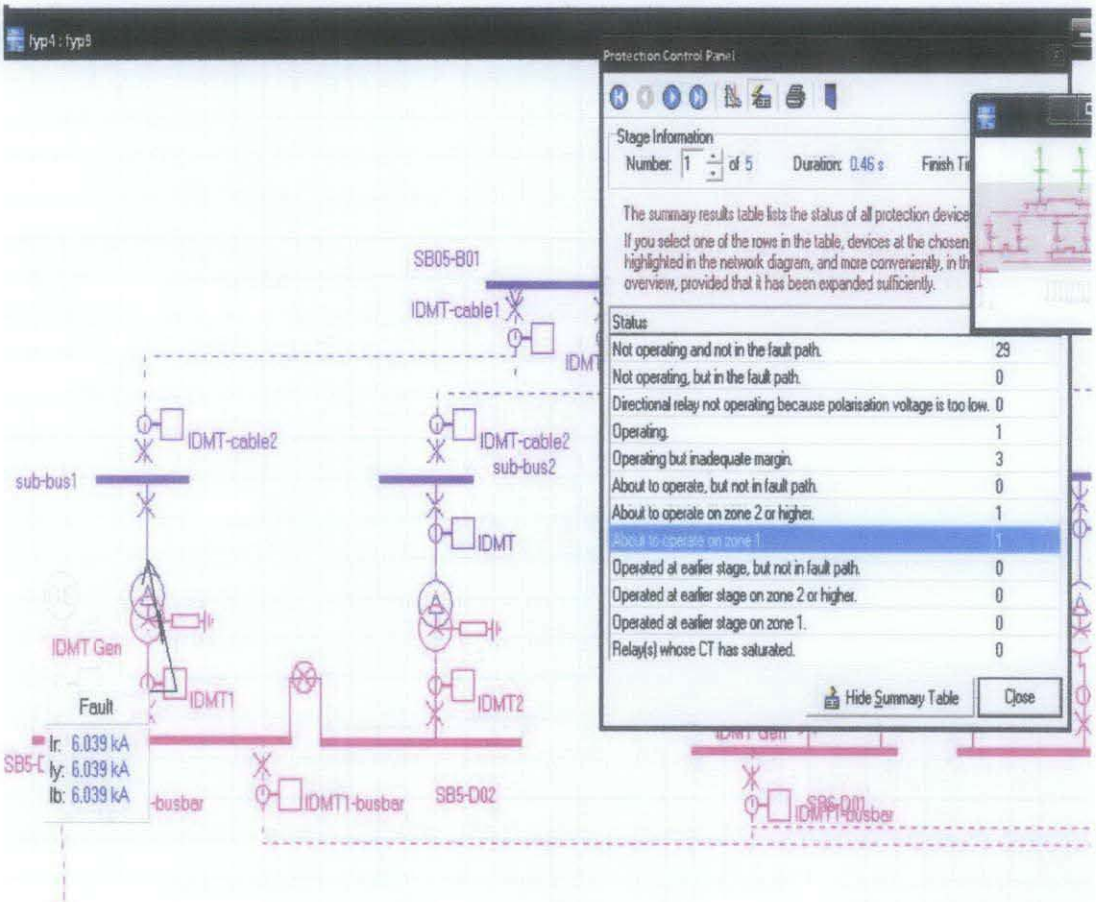


Figure 21: Result of Protection coordination IDMT

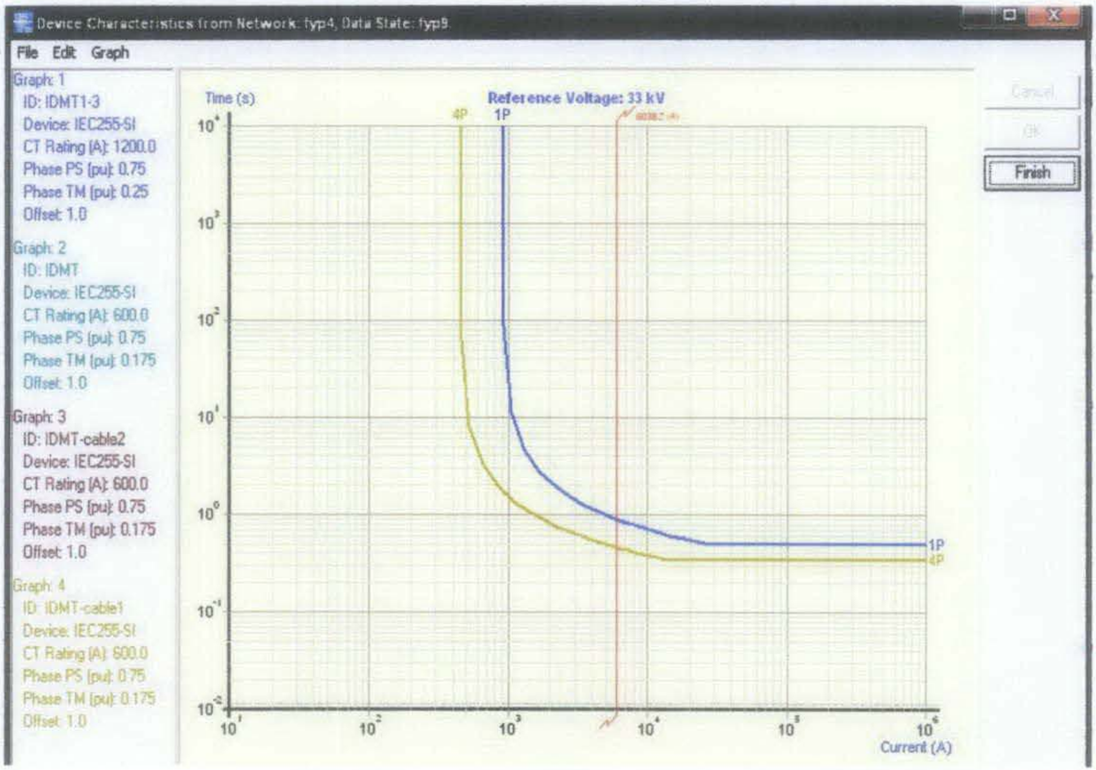


Figure 22: Graph for IDMT 1-3, IDMT cable 1, IDMT cable 1-2 and IDMT

From Figure 22, relay that has no margin will have the same characteristic, therefore the graph is about the same for all there relays; IDMT-cable1, IDMT-cable2 and IDMT. All three relays lay on the same graph as shown on the green line.

Therefore, value for all IDMT-cable1, IDMT-cable2 and IDMT relay is same:

Overcurrent setting: PS = 0.75

TMS = 0.175

4.2.2.4 IDMT 1

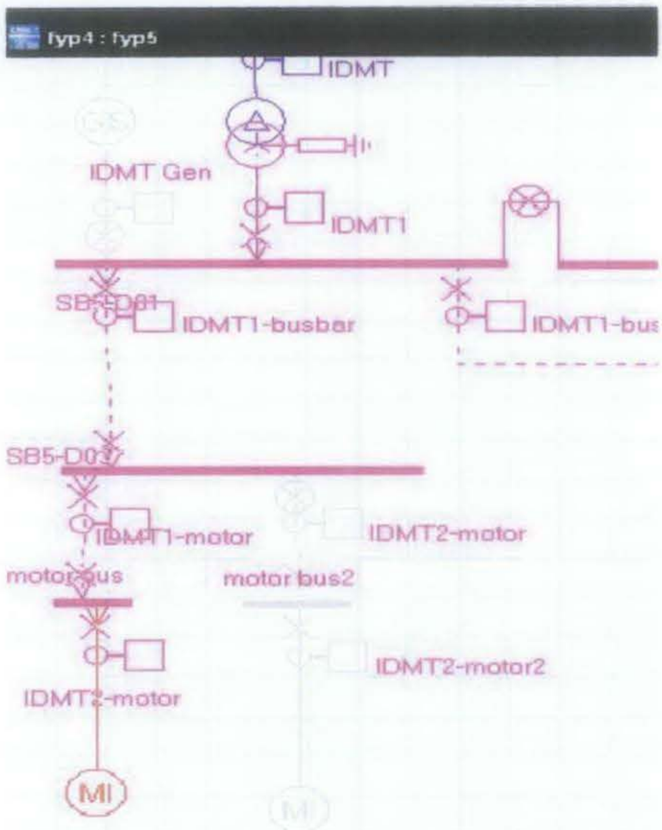


Figure 23: Location of IDMT 1, IDMT1-busbar, IDMT1-motor, and IDMT2-motor

For relay IDMT 1, the same step as use to grade IDMT 1-3 is apply to find the TMS value.

- For low voltage transformer relay, need to consider either 2 things:
  - Maximum operating current is 1.6 sec
  - Maximum remaining time is 0.2 sec

Therefore, value for IDMT 1

Overcurrent setting: PS = 0.70

TMS = 0.25

4.2.2.5 IDMT 1-busbar, IDMT 1-motor and IDMT 2-motor

To grade IDMT 1-busbar, its needs margin 0.4 sec with IDMT 1. Same steps goes to grade IDMT 1-motor, it is also needs 0.4 sec. But to grade IDMT 2-motor it does not need any margin to IDMT 1-motor since it is in the same feeder.

Therefore, value for all IDMT 1-busbar

Overcurrent setting: PS = 0.85

TMS = 0.15

Therefore, value for all IDMT 1-motor

Overcurrent setting: PS = 0.85

TMS = 0.05

Therefore, value for all IDMT 2-motor

Overcurrent setting: PS = 0.85

TMS = 0.05

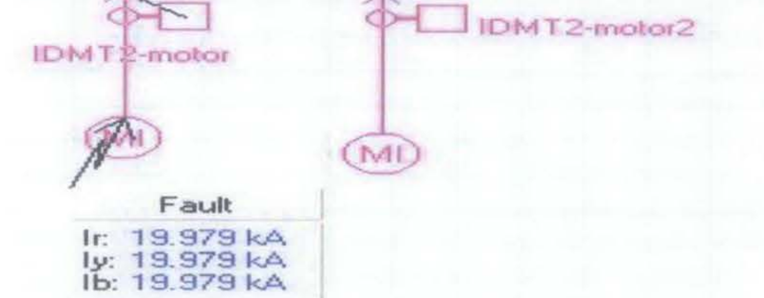


Figure 24: Result of protection coordination for IDMT2-motor

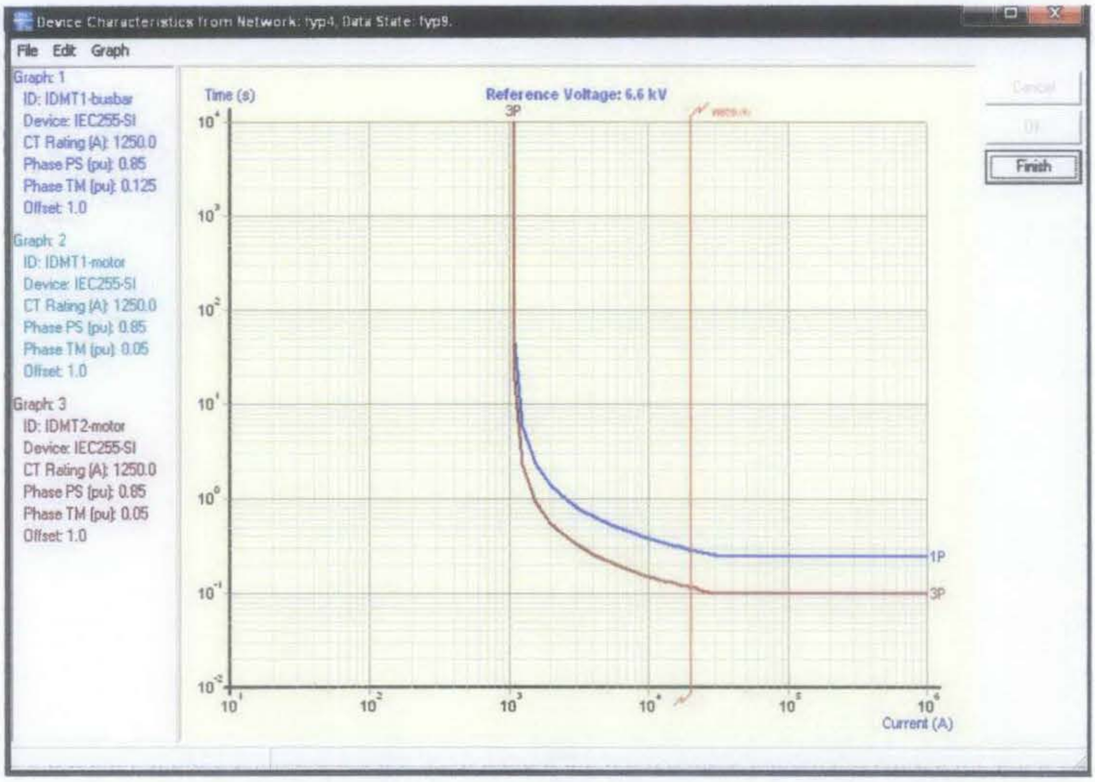


Figure 25: Graph for IDMT 1-busbar, IDMT 1-motor and IDMT 2-motor

The same steps apply to the other path but basically if the three phase fault current for the other path is same as the first path which have been discuss by the author above, the result for the relay TMS and PS is the same. But if there is a different in three phase fault current, than the author need to grade the relay again. From this project, three phase fault current is the same at the same level of voltage, therefore the author just need to grade the first path and can obtain the other coordination of relays.

4.2.3 Relay Coordination for Earthfault Protection

As in literature review, to grade relay for earthfault protection, need to consider earthfault condition. Since earthfault always occur and to prevent its trip on unbalanced load, the earthfault must be set 20% of its current carrying therefore, it will operate faster than overcurrent relay.

4.2.3.1 Current at 132 kV

$$I = 20\% \times I_{FL} = 0.2 \times 218.69A = 43.738A$$

$$PS = \frac{Full\ load\ current}{CT\ ratio} = \frac{43.738}{600} = 0.073$$

- Choose nearest PS available = 0.075

With PS at 0.075, the minimum available earthfault current that relay can carry is

$$I_{Min} = 0.075 \times CT\ Ratio = 0.075 \times 600 = 45A$$

Therefore, minimum current that is allowable to flow through the 132kV earthfault relay is 45A.

4.2.3.2 Current at 33 kV

$$I_{OC} = 20\% \times I_{FL} = 0.2 \times 874.77 = 174.77A$$

$$PS = \frac{Full\ load\ current}{CT\ ratio} = \frac{174.77}{1200} = 0.146$$

- Choose nearest PS available = 0.15

With PS at 0.15, the minimum available earthfault current that relay can carry is

$$I_{Min} = 0.15 \times \text{CT Ratio} = 0.15 \times 1200 = 180\text{A}$$

Therefore, minimum current that is allowable to flow through the 33kV earthfault relay is 180A.

The same steps use to calculate other equipments rating such as at the second transformer 33/6.6 kV transformer and motor rating. The result for the first path for earthfault protection as table below:

Table 5: List of Plug Setting for Earthfault Protection

Relay	CT Ratio	20% of full load current	Plug Setting (PS)	Allowable current
IDMT 1-1	600/1	43.74	0.075	45
IDMT 1-2	600/1	43.74	0.075	45
IDMT 1-3	1200/1	174.95	0.15	180
IDMT cable 1	600/1	87.48	0.15	90
IDMT cable 2	600/1	87.48	0.15	90
IDMT	600/1	87.48	0.15	90
IDMT 1	3000/1	418.37	0.15	420
IDMT Busbar	1250/1	209.95	0.20	250
IDMT 1 motor	1250/1	209.95	0.20	250
IDMT 2 motor	1250/1	209.95	0.20	250

4.2.4 Grading Margin for Earthfault Protection

The available values for TMS and PS for incoming 33kV/6.6kV transformer is given by the plant supervisor to help the author start grading margin for earthfault protection. The values are:

Earthfault setting: PS = 0.10

TMS = 0.10

This value is for IDMT-cable 1, IDMT-cable2 and IDMT. But refer to the Relay Coordination for Earthfault Protection calculation, PS is 0.15. Therefore the author uses this value to start with.

4.2.4.1 IDMT 1-1, IDMT 1-2

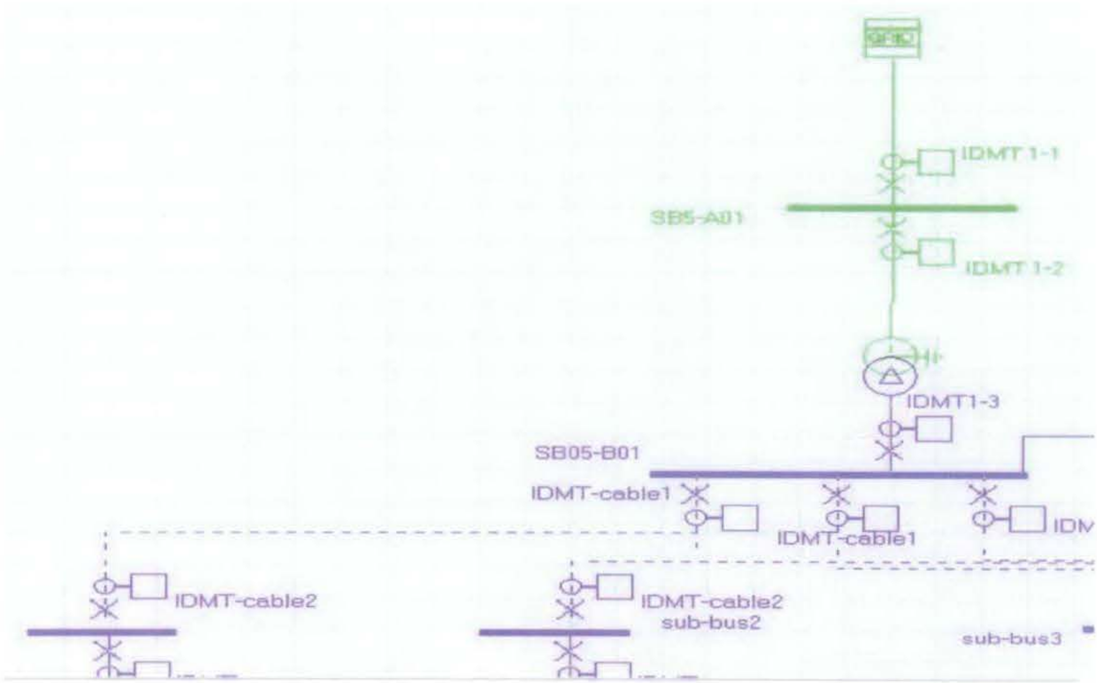


Figure 26: Location of relays

Start grading the network from grid 1 for IDMT 1-1 for earthfault relay protection. The grid 1 is from PAKA132_M1 substation which has the characteristic as in Table 4 above

The same characteristic apply here as in overcurrent protection. Since both relays are in the same feeder, therefore it does not need any margin. The author set the IDMT 1-2 TMS same as IDMT 1-1.

Earthfault setting IDMT1-1 and IDMT1-2: PS = 0.05

TMS = 0.05

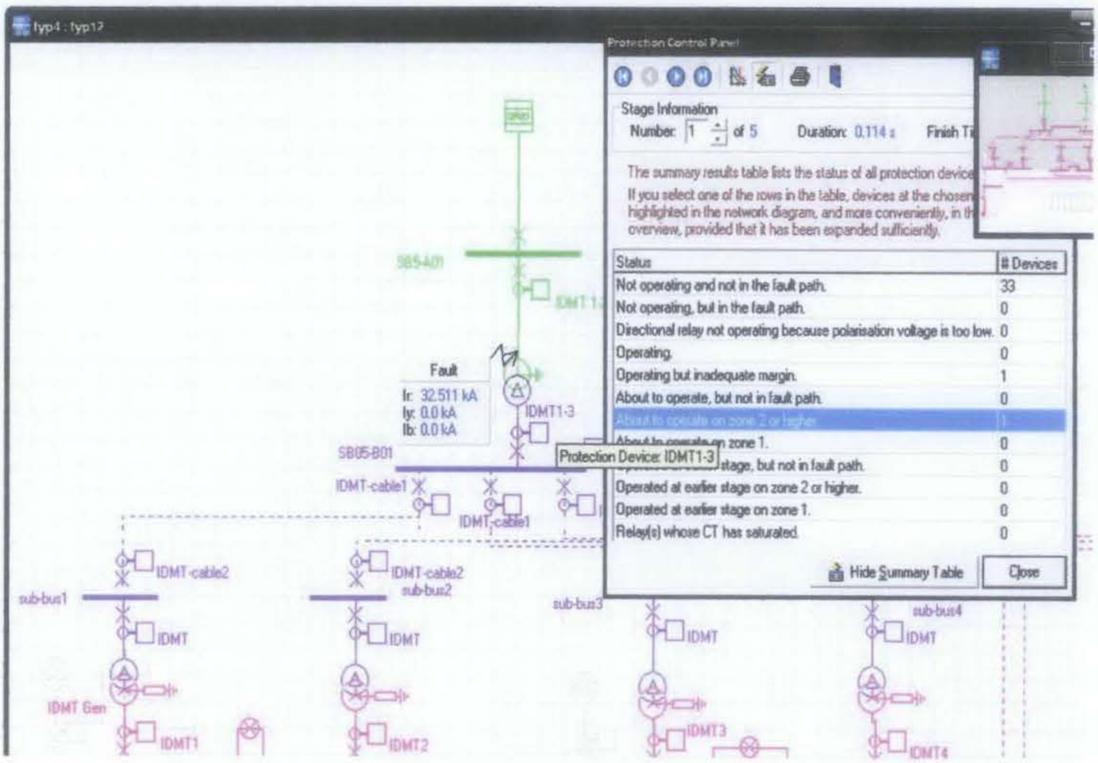


Figure 27: Result of Earthfault Protection Coordination for IDMT 1-2

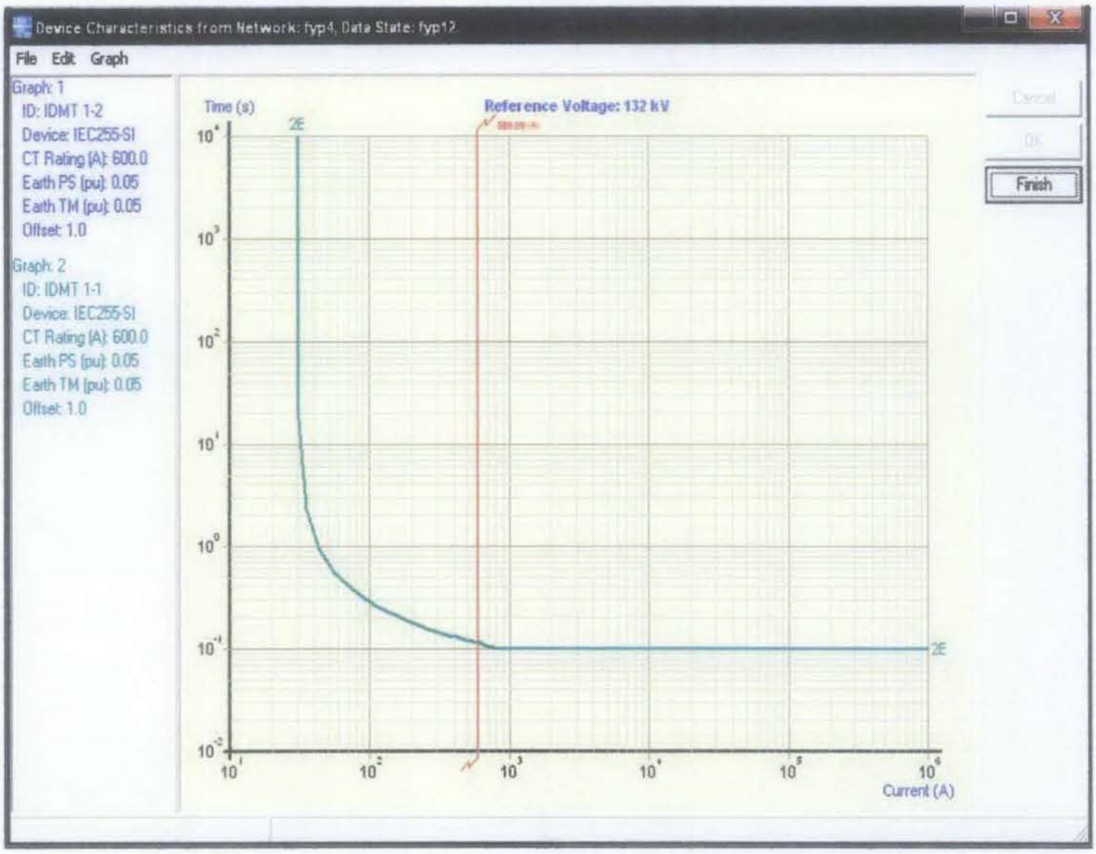


Figure 28: Graph for Earthfault Protection for relay IDMT 1-1 and IDMT 1-2

4.2.4.2 IDMT 1-3, IDMT cable-1, IDMT cable-2 and IDMT

The problem occurs to grade relay IDMT 1-3, IDMT cable-1, IDMT cable-2 and IDMT. Note that earthfault protection for relay located at low voltage transformer must be grade with overcurrent relay located at high voltage transformer. For this project earthfault relay IDMT1-3 must be grade with overcurrent relay IDMT1-2. Therefore the author uses this characteristic to grade IDMT 1-3.

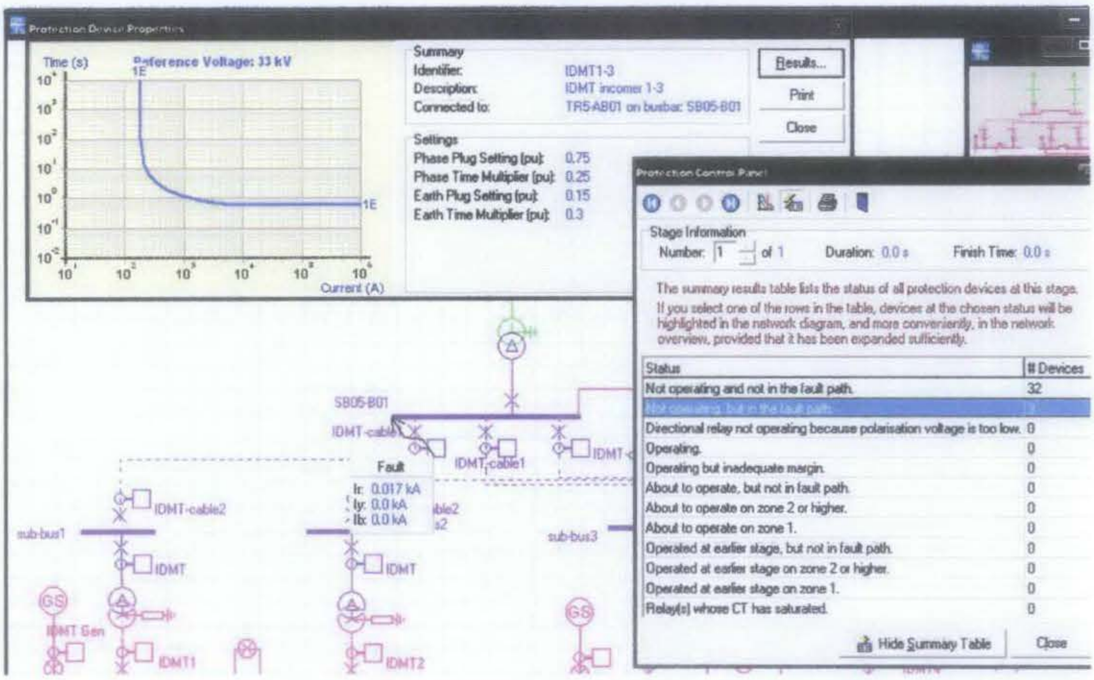


Figure 29: Result for Earthfault Protection for relay IDMT 1-3

Refer to the Figure 29, the single phase to ground fault current is too small. The current is just 17A and the IDMT 1-3 relay cannot detect such a small current.

This occurs because of transformer connection. Transformer 132kV/33kV use star-delta connection with solid grounded at star side. The star side connected to the supplier which is TNB while the delta side is connected to the load. Other than that, delta-star connection is use for transformer 33kV/6.6kV. The delta connection is at high voltage side which is connected to the delta connection low voltage side 132kV/33kV transformer. Therefore the unbalanced current is circulating around delta connection and not returns to ground. While this happen, the supplier which is TNB cannot detect this unbalanced occur.

Therefore, relay at this path which is IDMT1-3, IDMT cable-1, IDMT cable-2 and IDMT only can detect if there is overcurrent occur not for earthfault. This may risk the plant while operating this relays.

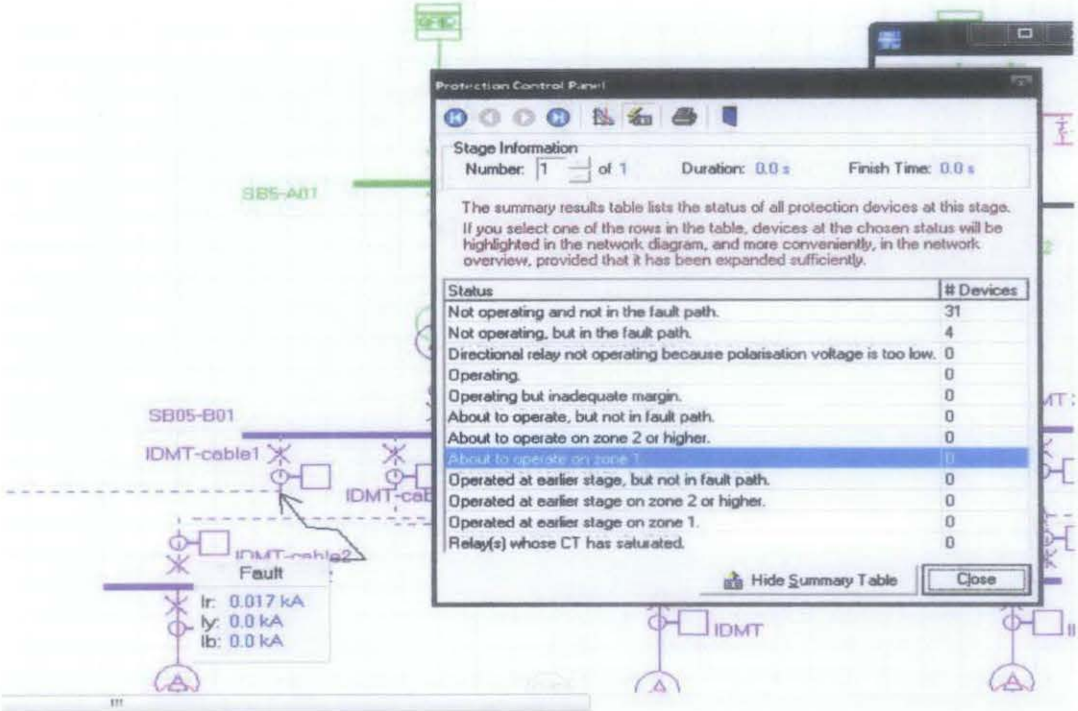


Figure 30: Earthfault current at Cable 1

Figure 31: Graph for Earthfault current IDMT1-cable

4.2.4.3 IDMT 1

IDMT 1 relay located at low voltage transformer, therefore it must be grade with overcurrent relay IDMT. The result that we have as Figure 32 and Figure 33.

We can see that from the graph, the earthfault line never cross the IDMT relay graph. The author set the TMS value so that it meets the requirement for the next relay to operate.

Earthfault setting: PS = 0.15

TMS = 0.25

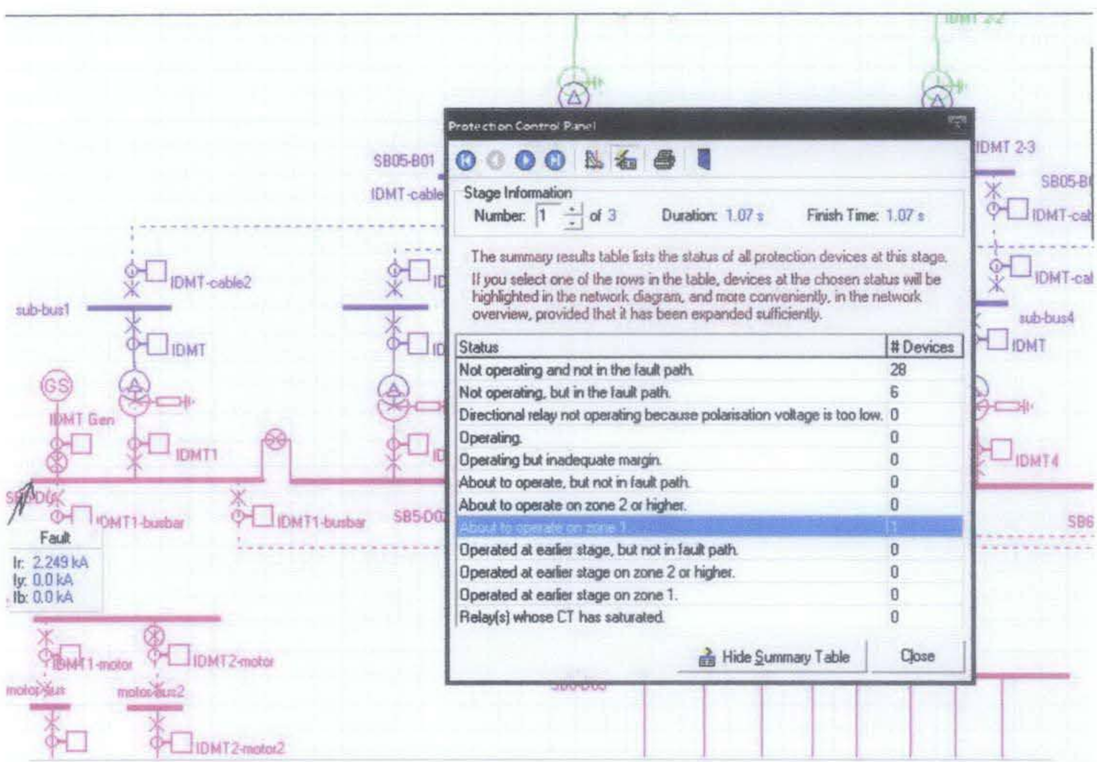


Figure 32: Result Earthfault current for IDMT1

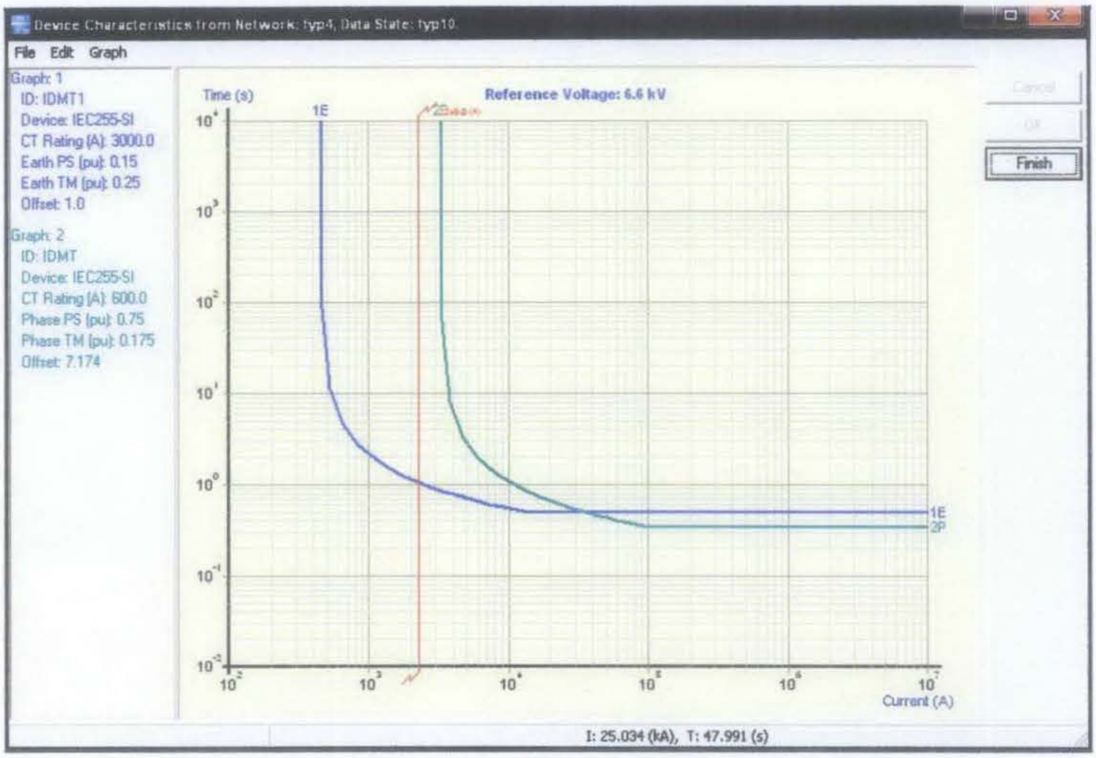


Figure 33: Graph for Earthfault current IDMT1-cable

4.2.4.4 IDMT1-busbar, IDMT1-motor and IDMT2-motor

The same method use to grade this relays as overcurrent relays. Since IDMT1-busbar and IDMT1-motor relays located at different feeder than the margin with the previous relay must be 0.4 sec, but there is no margin required for IDMT2-motor because it is in the same feeder.

Therefore, for IDMT1-busbar

Earthfault setting: PS = 0.20

TMS = 0.22

IDMT1-motor

Earthfault setting: PS = 0.20

TMS = 0.05

IDMT2-motor

Earthfault setting: PS = 0.20

TMS = 0.05

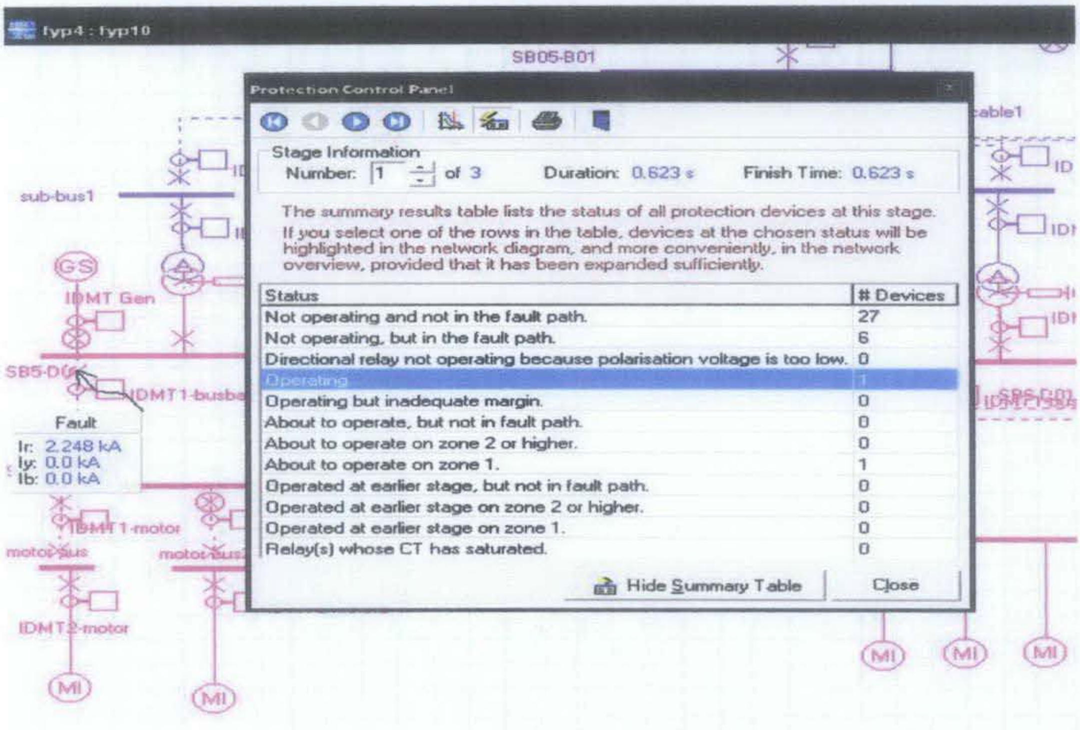


Figure 34: Result IDMT1-busbar for Earthfault Protection

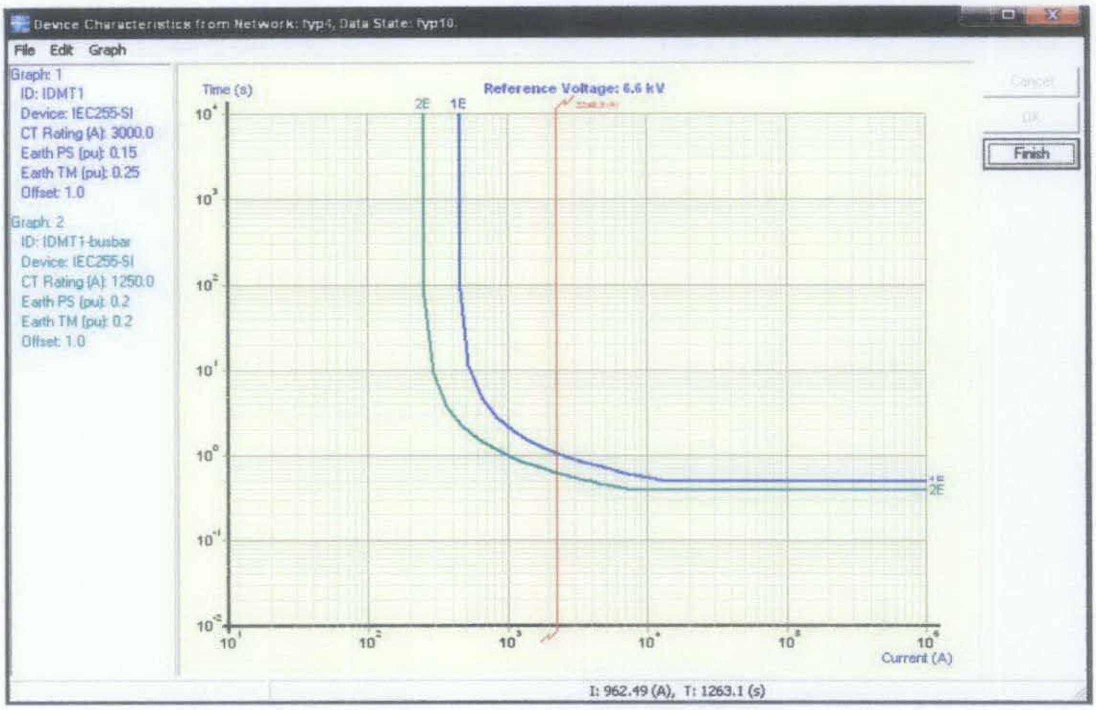


Figure 35: Graph for IDMT 1 and IDMT 1-busbar

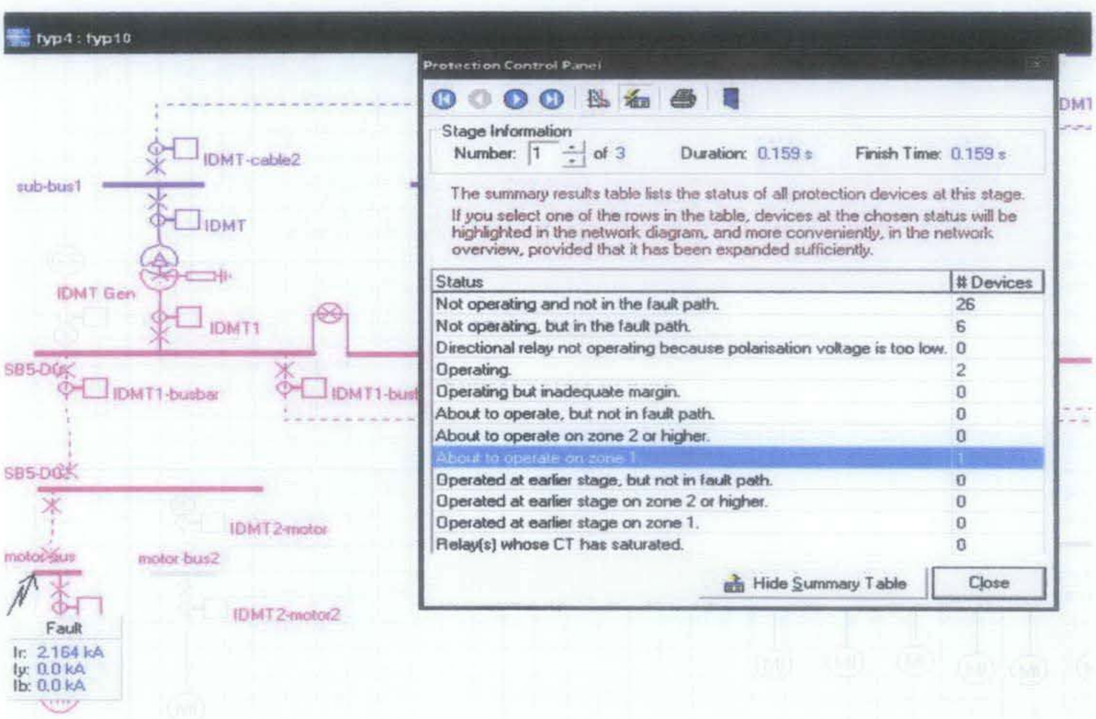


Figure 36: Result IDMT1-motor for Earthfault Protection

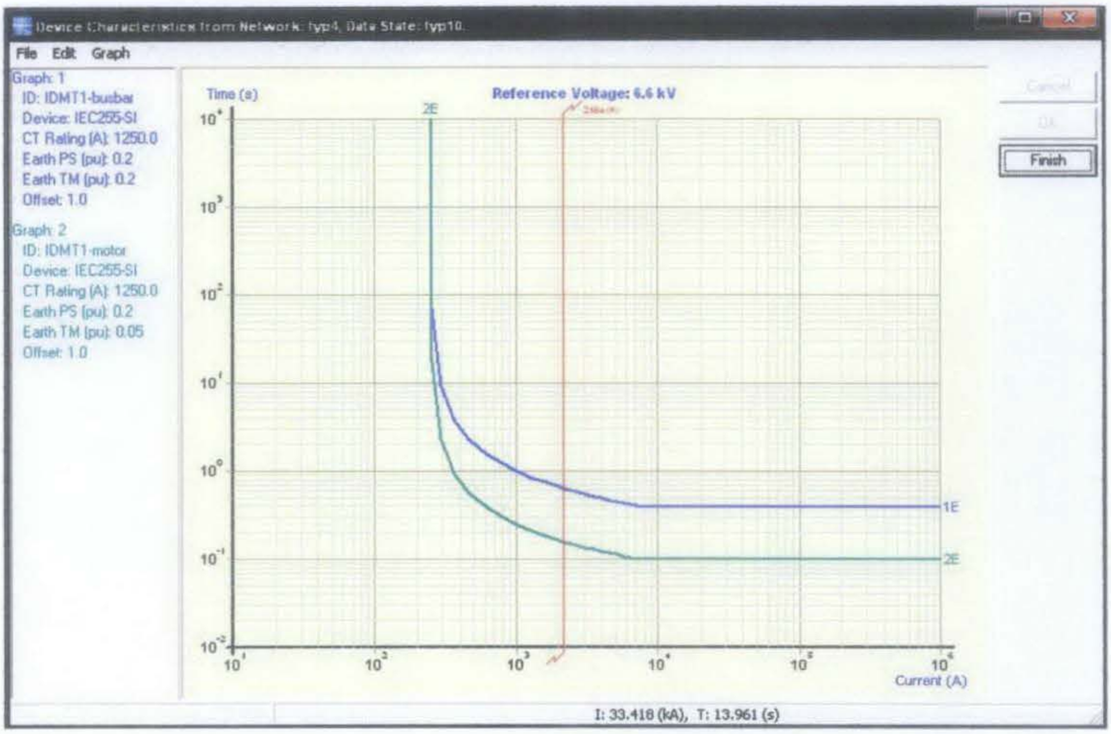


Figure 37: Graph for IDMT1-busbar and IDMT1-motor

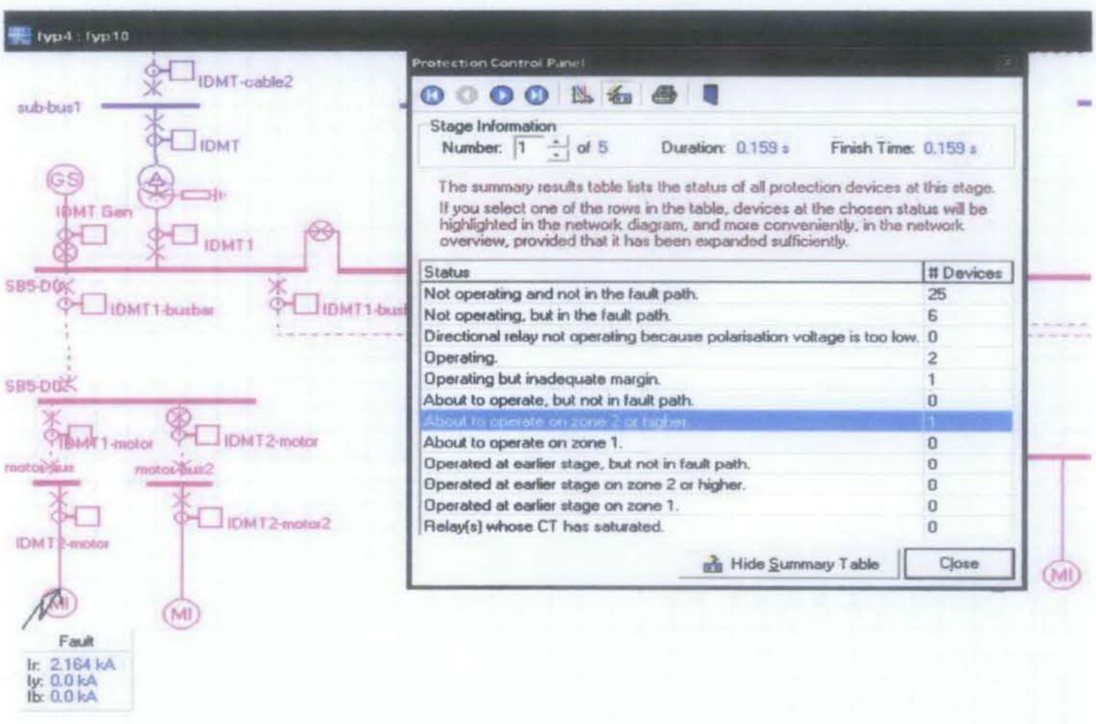


Figure 38: Result IDMT2-motor for earthfault protection

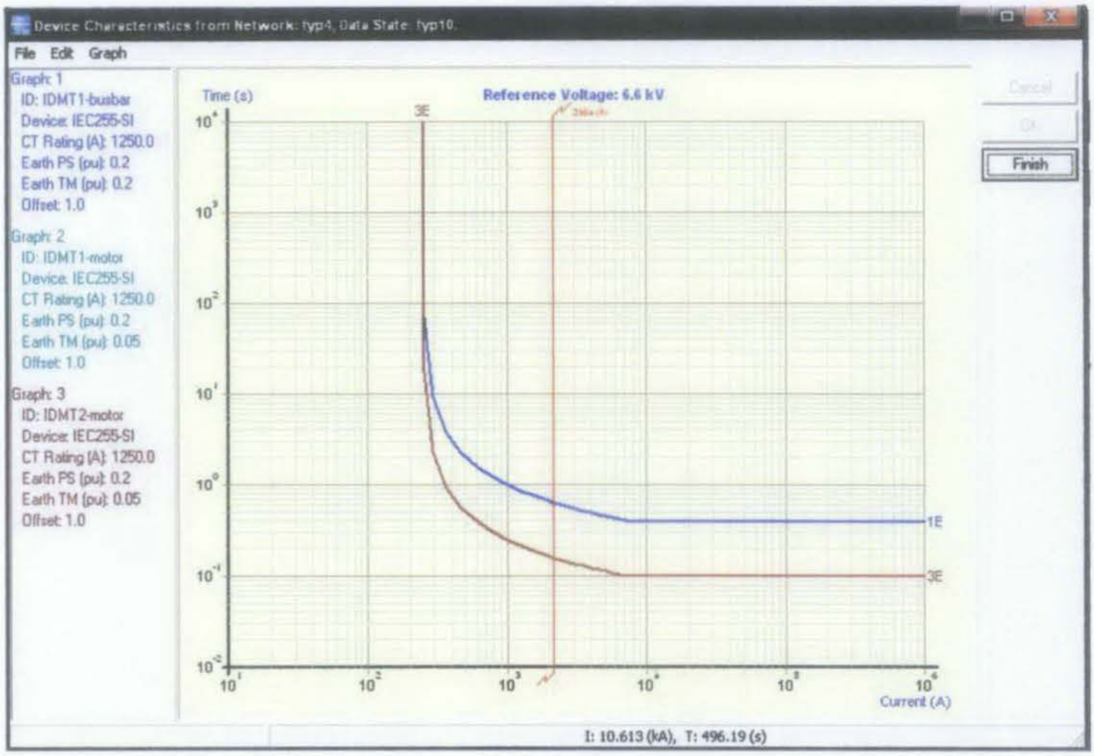


Figure 39: Graph for IDMT1-busbar, IDMT1-motor and IDMT2-motor

The same steps apply to the other path but basically if the earthfault current for the other path is same as the first path which have been discuss by the author above, the result for the relay TMS and PS is the same. But if there is a different in earthfault current, than the author need to grade the relay again. From this project, earthfault current is the same at the same level of voltage, therefore the author just need to grade the first path and can obtain the other coordination of relays.

CHAPTER 5

CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

This project, basically study on current protection coordination at GPPB. Main objective of the project is to do grading margin for overcurrent and earthfault protection from the source-TNB to the high voltage system is 6.6 kV motor so that it meet all the requirements (stable, selective, sensitive, fast and reliable) to operate safely to human life also to the other electrical component. For overcurrent it related to 3-phase current fault and for earthfault it is related to the single phase to ground fault. Both current faults needed in order to grade the relay. The best coordination need to be find by getting the Plug setting (PS) and also Time Multiplier setting (TMS) for the relay. These two components is a setting of the relay to determine time for relay to operate. At the end, the coordination for overcurrent and earthfault can be achieved

The author finished design the network inside ERACS software for high voltage network and finished design the grading margin for the first path. While doing the grading, the problem occur where the given Plug Setting (PS) and Time Multiplier (TMS) value by the plant supervisor is too small and some consideration such as:

1. Consider the maximum remaining time is 0.2 sec for relay at low voltage transformer
2. Relay for bus that have only one feeder no need margin

From the result, the author cannot compare TMS and PS value with the real value use at plant because the author cannot gets all TMS and PS setting values. But still with the available value, there is different in PS value calculated and real use at plant for earthfault protection relay.

A lot of lessons that the author learnt from this project which cannot be get in class. The author learnt the steps taken to do grading margin, some characteristics that need to be considered while grading, and learnt the usage of ERACS software as one of the software use in Power system.

5.2 Recommendations

There are some recommendations that the author would suggest to be implemented and corrected for this project:

1. Refer to the Relay Coordination for Earthfault Protection calculation, there is a different in PS value for IDMT-cable1. The value should be 0.15 for PS rather than 0.1 for PS use at plant.
2. The use of star-delta connection at 132kV/33kV is not suitable because the earthfault current is too small at load side. The relay cannot detect if there is earthfault occur and can only trip if the overcurrent or three phase fault occur. The author suggests replacing the transformer with delta-star connection
3. Value for NER use at plant is 10Ω at 33kV/6.6kV. But after calculation, the author suggest to use NER = 1.82Ω.

$$I_{FL} = \frac{MVA}{\sqrt{3} \times VLL} = \frac{25\,MVA}{\sqrt{3} \times 6.9kV} = 2091.85A$$

$$NER = \frac{single\ phase\ voltage}{full\ load\ current} = \frac{6.6kV/\sqrt{3}}{2091.85} = 1.82\Omega$$

REFERENCES

[1] *IEM Professional Interview Report*, Protection Relay Coordination and Protection Equipment Commissioning Testing of the 22KV Main Switch Station (SSU) Satera Maju Project, Tenaga Nasional Berhad (TNB) Ipoh, Perak.

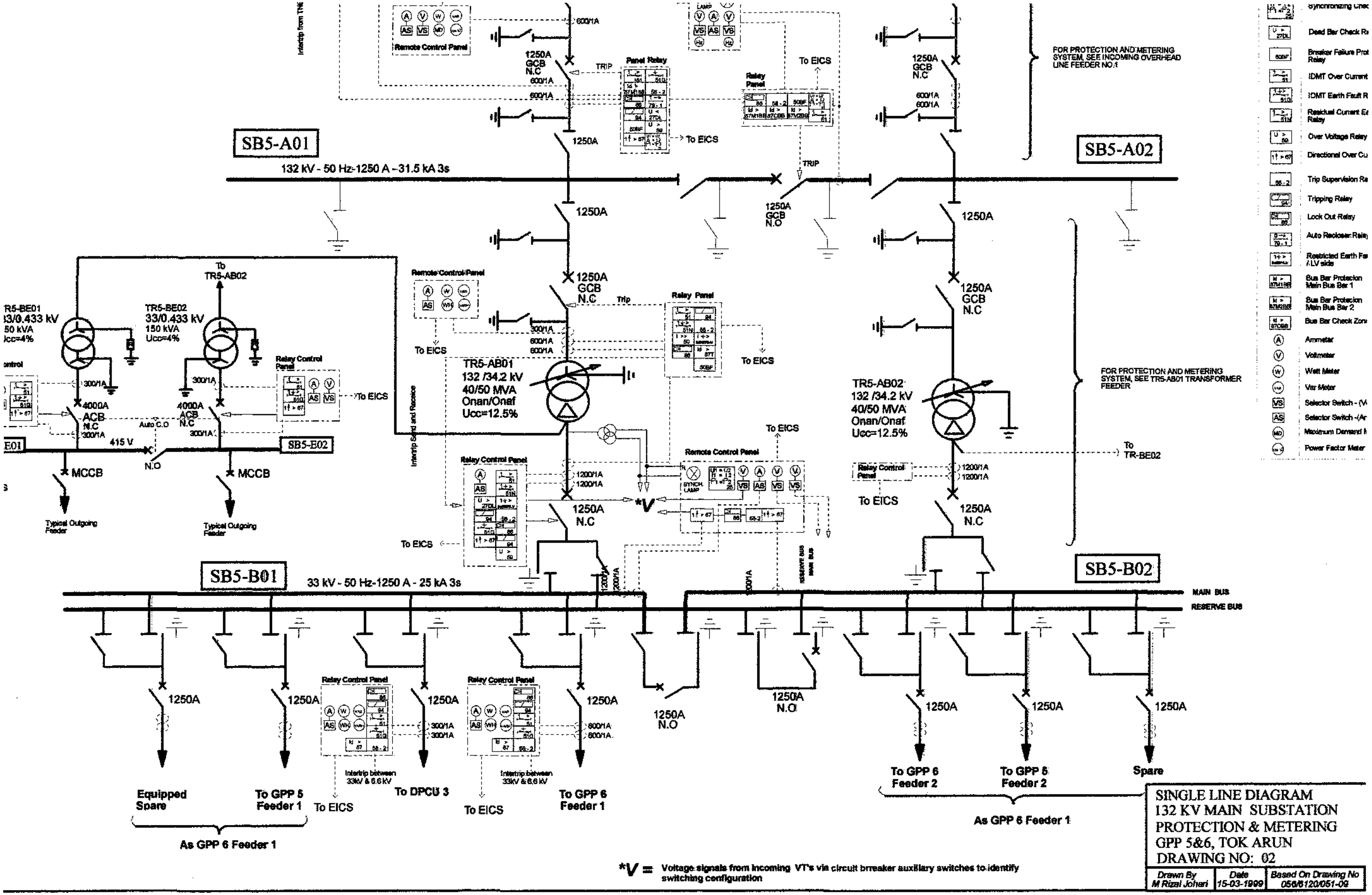
[2] Hadi Saadat, *Power System Analysis*, Second Edition. McGRAW-HILL INTERNATIONAL EDITION, Electrical Engineer Series.

[3] John J. Grainger and William D. Stevenson, Jr. *Power System Analysis*, McGRAW-HILL INTERNATIONAL EDITION, Electrical Engineer Series.

[4] *A Guide book on Distribution Protection – Coordination of Protective Device* from Tenaga Nasional Berhad

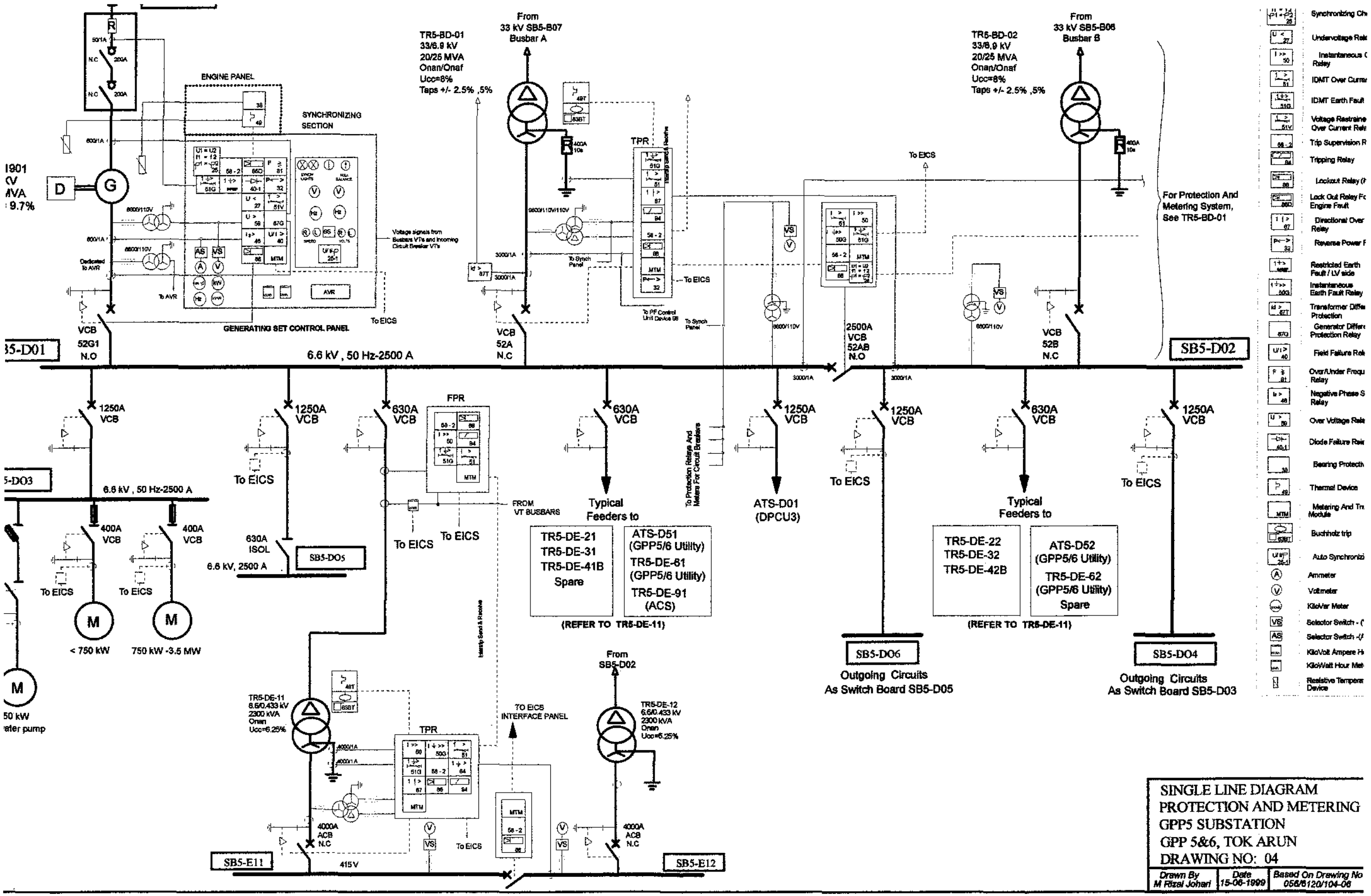
[5] *Distribution Protection System note* by Unit Perlindungan (Kedah/Perlis) Tenaga Nasional Berhad.

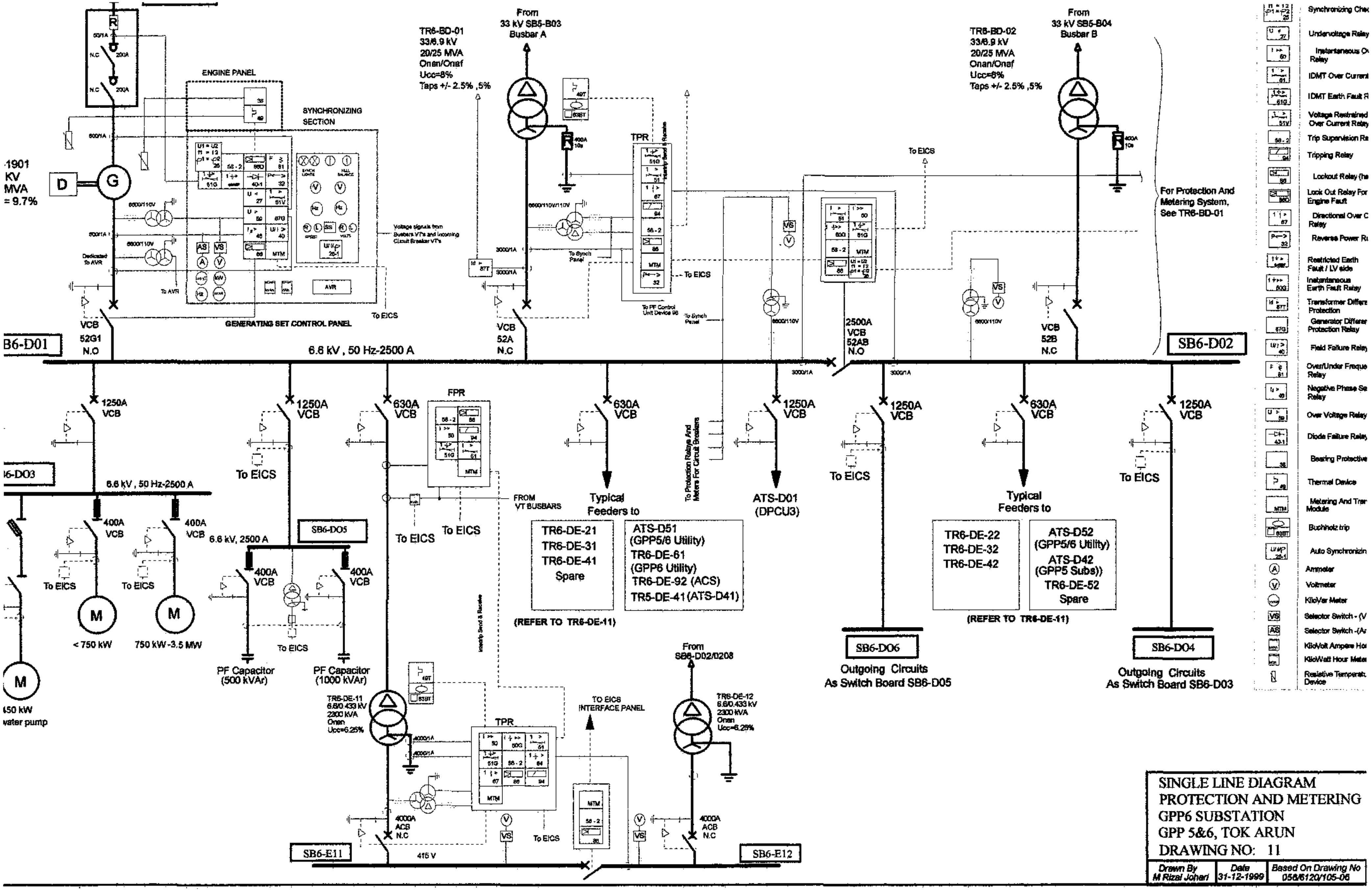
Appendixes



SINGLE LINE DIAGRAM
132 KV MAIN SUBSTATION
PROTECTION & METERING
GPP 5&6, TOK ARUN
DRAWING NO: 02

Drawn By	Date	Based On Drawing No
M Rizal Johari	15-03-1999	056/6120/051-09


ENGINE PANEL
SYNCHRONIZING SECTION
GENERATING SET CONTROL PANEL
D
G
To AVR
To EICS
VCB
52G1
N.O
6.6 kV , 50 Hz-2500 A
TR5-BD-01
33/6.9 kV
20/25 MVA
Onan/Onaf
Ucc=8%
Taps +/- 2.5% ,5%
From
33 kV SB5-B07
Busbar A
TPR
To EICS
VCB
52A
N.C
To PF Control Unit Device 58
To Synch Panel
2500A
VCB
52AB
N.O
TR5-BD-02
33/6.9 kV
20/25 MVA
Onan/Onaf
Ucc=8%
Taps +/- 2.5% ,5%
From
33 kV SB5-B06
Busbar B
For Protection And Metering System, See TR5-BD-01
VCB
52B
N.C
SB5-D01
SB5-D02
1250A VCB
630A VCB
FPR
SB5-D03
6.6 kV , 50 Hz-2500 A
400A VCB
To EICS
M
< 750 kW
750 kW -3.5 MW
630A ISOL
6.6 kV, 2500 A
SB5-DO5
FROM VT BUSBARS
Typical Feeders to
TR5-DE-21
TR5-DE-31
TR5-DE-41B
Spare
ATS-D51
(GPP5/6 Utility)
TR5-DE-61
(GPP5/6 Utility)
TR5-DE-91
(ACS)
(REFER TO TR5-DE-11)
To Protection Relays And Meters For Circuit Breakers
ATS-D01
(DPCU3)
SB5-DO6
Outgoing Circuits
As Switch Board SB5-D05
TR5-DE-22
TR5-DE-32
TR5-DE-42B
ATS-D52
(GPP5/6 Utility)
TR5-DE-62
(GPP5/6 Utility)
Spare
(REFER TO TR5-DE-11)
SB5-DO4
Outgoing Circuits
As Switch Board SB5-D03
TR5-DE-11
6.6/0.433 kV
2300 kVA
Onan
Ucc=6.25%
TPR
TO EICS INTERFACE PANEL
From SB5-D02
TR5-DE-12
6.6/0.433 kV
2300 kVA
Onan
Ucc=6.25%
4000A ACB N.C
SB5-E11
415V
SB5-E12
Synchronizing Check
Undervoltage Relay
Instantaneous Over Current Relay
IDMT Over Current
IDMT Earth Fault
Voltage Restrained Over Current Relay
Trip Supervision Relay
Tripping Relay
Lockout Relay
Lock Out Relay For Engine Fault
Directional Over Current Relay
Reverse Power
Restricted Earth Fault / LV side
Instantaneous Earth Fault Relay
Transformer Differential Protection
Generator Differential Protection Relay
Field Failure Relay
Over/Under Frequency Relay
Negative Phase Sequence Relay
Over Voltage Relay
Diode Failure Relay
Bearing Protection
Thermal Device
Metering And Transducer Module
Buchholz trip
Auto Synchronizer
Ammeter
Voltmeter
KiloVar Meter
Selector Switch
Selector Switch
KiloVolt Ampere Hour Meter
KiloWatt Hour Meter
Resistive Temperature Device
SINGLE LINE DIAGRAM
PROTECTION AND METERING
GPP5 SUBSTATION
GPP 5&6, TOK ARUN
DRAWING NO: 04
Drawn By M Rizal Johari
Date 15-06-1999
Based On Drawing No 056/6120/104-06


From
33 kV SB5-B03
Busbar A
TR6-BD-01
33/6.9 kV
20/25 MVA
Onan/Onaf
Ucc=8%
Taps +/- 2.5% ,5%
From
33 kV SB5-B04
Busbar B
TR6-BD-02
33/6.9 kV
20/25 MVA
Onan/Onaf
Ucc=8%
Taps +/- 2.5% ,5%
ENGINE PANEL
SYNCHRONIZING SECTION
GENERATING SET CONTROL PANEL
TPR
To EICS
For Protection And Metering System, See TR6-BD-01
VCB
52G1
N.O
VCB
52A
N.C
2500A
VCB
52AB
N.O
VCB
52B
N.C
SB6-D02
6.6 kV , 50 Hz-2500 A
1250A VCB
630A VCB
FPR
To EICS
6.6 kV , 50 Hz-2500 A
400A VCB
M
< 750 kW
750 kW -3.5 MW
450 kW water pump
SB6-D05
6.6 kV, 2500 A
PF Capacitor (500 kVAr)
PF Capacitor (1000 kVAr)
FROM VT BUSBARS
Typical Feeders to
TR6-DE-21
TR6-DE-31
TR6-DE-41
Spare
ATS-D51
(GPP5/6 Utility)
TR6-DE-61
(GPP6 Utility)
TR6-DE-92 (ACS)
TR5-DE-41 (ATS-D41)
(REFER TO TR6-DE-11)
To Protection Relays And Meters For Circuit Breakers
ATS-D01
(DPCU3)
TR6-DE-22
TR6-DE-32
TR6-DE-42
ATS-D52
(GPP5/6 Utility)
ATS-D42
(GPP5 Subs))
TR6-DE-52
Spare
(REFER TO TR6-DE-11)
SB6-D06
Outgoing Circuits As Switch Board SB6-D05
SB6-D04
Outgoing Circuits As Switch Board SB6-D03
From SB6-D02/0208
TO EICS INTERFACE PANEL
TR6-DE-11
6.6/0.433 kV
2300 kVA
Onan
Ucc=6.25%
TR6-DE-12
6.6/0.433 kV
2300 kVA
Onan
Ucc=6.25%
4000A ACB N.C
SB6-E11
415 V
SB6-E12
Synchronizing Check
Undervoltage Relay
Instantaneous Over Current Relay
IDMT Over Current
IDMT Earth Fault Relay
Voltage Restrained Over Current Relay
Trip Supervision Relay
Tripping Relay
Lockout Relay
Lock Out Relay For Engine Fault
Directional Over Current Relay
Reverse Power Relay
Restricted Earth Fault / LV side
Instantaneous Earth Fault Relay
Transformer Differential Protection
Generator Differential Protection Relay
Field Failure Relay
Over/Under Frequency Relay
Negative Phase Sequence Relay
Over Voltage Relay
Diode Failure Relay
Bearing Protective
Thermal Device
Metering And Transducer Module
Buchholz trip
Auto Synchronizing
Ammeter
Voltmeter
KiloVar Meter
Selector Switch - (V)
Selector Switch -(A)
KiloVolt Ampere Hour
KiloWatt Hour Meter
Resistive Temperature Device
SINGLE LINE DIAGRAM
PROTECTION AND METERING
GPP6 SUBSTATION
GPP 5&6, TOK ARUN
DRAWING NO: 11
Drawn By
M Rizal Johari
Date
31-12-1999
Based On Drawing No
056/6120/105-06