Sudan University of Science and Technology

College of Engineering

Electrical Engineering

Over Current And Earth Fault Protection Coordination By ETAP

تنسيق حماية التيار الزائد والخطأ الأرضي بواسطة ETAP

A Project Submitted In Partial Fulfillment For The Requirement

Of the Degree of B.Sc. (honor) In Electrical Engineering

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الآيـة

قال تعالى:

(قالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ)

صدق لله العظيم

سورة البقرة الاية 34)

DEDICATION

To our Mothers: A Strong and Gentle Soul Who Taught us to Trust Allah Believe In Hard Work and the So Much Could Be Done With Little.

Our Fathers: For Earning an Honest Living for Us and For Supporting and Encouraging us to Believe In ourself.

Our Brothers and Sisters: for their help and Passion.

Our Friends: a great people whose standing with us when we need support.

ACKNOWLEDGEMENT

All the thanks, praises and glorifying is due to Almighty ALLAH I owe our deepest gratitude to our advisor Dr. Alfadil Zakria First for accepting us as a students, then for the support and help he has given us throughout the project.

Many thanks to our colleagues and all the staff at the Department Of Electrical And Nuclear Engineering for the pleasant working atmosphere and your friendship.

Finally, we would like to thank all those who helped us supported us and lots of thanks to our family.

ABSTRACT

Continuous and reliable power supply is the main goal and target for power system networks. In this regard, many methods have been developed to enhance the performance of power supply systems.

The case study is initiated to investigate power system network by using ETAP software as analysis tool. The network was drawn. The data for each component in the network was entered.

After running the simulator, different fault scenarios were created to examine the existing protection system schemes and different miss-operations results were obtained as a response of protection system to the abnormal conditions.

A new coordination scheme is designed which starts first by coordinating the 3phase over-current elements, for different paths .

Next the earth fault relays are coordinated for the same paths and finally the instantaneous element as a backup protection was applied successfully.

المستخلص

منظومة القوي الكهربية واحده من أهم وأعظم المنظومات التي صنعها الإنسان وأكثرها تعقيدا ويعتبر إمداد الطاقة بشكل مستمر وموثوق احد اهم العوامل الي تؤثر على كفاءة المنظومة، لذلك تم ابتكار العديد من الأنظمة والطرق واستخدمت العديد من الوسائل من أجل تحسين الأداء وضمان استمرار إمداد الطاقة بالصورة المطلوبة.

تم عمل هذا البحث بدراسة لمنظومة شبكه كهربائية باستخدام برنامج "إي تاب"كأداة للدراسة والتحليل ثم رسم وتمثيل الشبكة ومن ثم إدخال البيانات الخاصة بجميع عناصر الشبكة في البرنامج.

تم اختبار أنظمة الحماية حالية عن طريق عمل سيناريوهات لاعطال كهربائية وتم الحصول عل بعض الاستجابات الخاطئة من نظام الحماية لهذه الأعطال.

تم تقسيم الشبكة إلى مناطق وصمم نظام تنسيق جديد للمرحلات هذا النظام يبدا بتسيق عناصر مراقبة التيار لثلاثه اطوار وذلك للمناطق بالتتابع في مسارات لشبك .

كذلك تم تنسيق مرحلات حماية الأعطال للخطأ الأرضي واخيرا تم تنسيق العناصر اللحظية كعناصر احتياطيه للحماية .

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CHAPTER ONE

INTRODUCTION

1.1 Overview

One of the important roles of protection system is to isolate the faulted zone while keeping the healthy ones in service at correct time, i.e., discrimination or selectivity, especially in industrial areas where the continuity of power is a very crucial matter, this can be achieved by proper relays coordination using time delayed over current and earth protections.

1.2 Proplem Statement

Any error in the protection system - If it is not discovered fast enough- can cause huge damages for large parts of the system .

1.3 Objective

The objective of this study is to analyze and proposed a proper coordination setting to the protection relays. Takes AL-JENAID substation as a case study.

1.4 Methodology

The setting of over current and earth fault protection functions for transmission lines, outgoing feeders and transformers shall be coordinated. The coordination will be performed by using ETAP program which simulates all kinds of faults and shows clearly the time of tripping for any equipment included in the coordination study.

1.5 Project Layout

This thesis is divided into five chapters:

In the first chapter, the Overview of the protection and coordination, problem statement, methodology of research ,and objective of the project.

In the second chapter, the protection system schemes that are used to protect the equipment of the substations (transmission lines, busbars and transformers). are presented and explained.

In the third chapter deliberates on the methodology of Coordination in power system protection.

In the fourth chapter, the simulation study for over current and earth fault protection functions are presented by using ETAP.

In the fifth chapter we will go through the conclusion and recommendation for future study.

CHAPTER TWO

PROTECTION SHEMES

2.1 Protection Schemes at Substation

The concept of one main (Distance) and backup (Over current and Earth fault) for 110 KV lines, one main (transformer differential) and back up (Over current and Earth fault) for main transformers, and Over Current (O/C) and Earth Fault (E/F) for 33 KV outgoing feeders.

2.1.1 Distance protection

Can provide single and three pole tripping. 21G/21P: Phase and earth fault distance protection, each with up to 5 independent zones of protection and customized signaling schemes are available to give fast fault clearance for the whole of the protected line. The distance relays offer a comprehensive range of protection functions such as 79/25:autoreclosure with check synchronism, 50/51: Instantaneous and time delayed over current protection, 67N: Directional earth fault protection (DEF), 78 – 68: Power swing blocking [1].

2.1.2 Line differential

In case of transmission line, implementation of differential protection requires a communication channel to transmit current values to the other end. It can be used for short feeders and a specific implementation is known as pilot wire protection. Differential protection tends to be extremely accurate. Its zone is clearly demarcated by the CTs which provide the boundary, and the most important benefit of all; differential principle offers the most selective line protection.

2.1.3 Transformer differential

Time delayed clearance of major faults is unacceptable on larger distribution and transmission transformers, where the effects on system operation and stability must be considered. High speed protection (differential protection) is desirable for all faults. To provide effective protection for faults within a transformer and security for normal operation and external faults, some feature is use in differential relay like Magnetizing inrush current block.[2]

2.1.4 Busbar protection

Current differential busbar protection – Phase segregated biased differential protection (sometimes referred to as low impedance type), providing a high speed discriminative protection for all fault types in busbar zone. Circuit breaker failure protection (two stage breakers fail logic that can be initiated internally or externally) and dead zone protection – phase and neutral are incorporated in the relay.

2.1.5 Backup protection

For attaining higher reliability, quick action and improvements in operating flexibility of the protection schemes, separate elements of a power system, in addition to main or primary protection, are provided with a back-up and auxiliary protection. First in line of defense is main protection which ensures quick action and selective clearing of faults within the boundary of the circuit section or the element it protects. Main protection is essentially provided as a rule.

Backup protection gives back up to the main protection, when the main protection fails to operate or is cut out for repairs etc.

- Failure of the main protection may be due to any of the following reasons:

1. D.C supply to the tripping circuit fails.
2. Current or voltage supply to the relay fails.
3. Tripping mechanism of the circuit breaker fails.
4. Circuit breaker fails to operate.
5. Main protective relay fails.

Back up protection may be provided either on the same circuit breakers which will be opened by the main protection or may use different circuit breakers. Usually, more than the faulty section is isolated when the backup protection operates. Very often the main protection of a circuit acts as back up protection for the adjacent circuit. Back up protection is provided where main protection of the adjacent circuit fails to back up the given circuit. For simplification, back up protection can have a lower sensitivity factor and be operative over a limited back up zone i.e. be operative for only part of the protected circuit.

- Methods of back up protection can be classified as follows

1. Relay Back-up
2. Breaker Back-up
3. Remote Back-up
4. Centrally Co-ordinate Back-up

   Discrimination (location of fault, type of fault) can be determined by different methods (Time, Current Magnitude, Time + Current Magnitude Time + Direction of Current and Distance (V/I)).

- Back-up protection by Time Grading principle(independent):

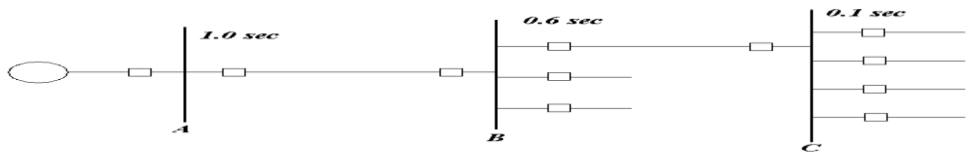

Figure 2.1: Back-up protection by time grading principle

In this method, current is measured at various points along the current path, for e.g., at source, intermediate locations, consumers end. The tripping time at these locations are graded in such a way that the circuit breaker nearest to the faulty section operates first, giving primary protection. The circuit breaker at the previous section operates only as a back-up.

In Figure2.1 the tripping time at sections C, B and A are graded such that for a fault beyond C, breaker at C operates as a primary protection. Relays at A and B also may start operating but they are provided with enough time lags so that breaker at B operates only if breaker at C does not. Thus, for a fault beyond C, breaker at C will operate after 0.1 second. If it fails to operate, the breaker at B will operate after 0.6 second (Back-up for C) and if the breaker at B also fails to operate, breaker at A will operate after 1 second (Back-up for B and C) [3].

- Back-up protection by inverse current time Grading principle(dependent):

Generally, the operation time is inversely proportional to the applied current, and there are four types of characteristics (Standard or Normal Inverse, Very Inverse, Extremely Inverse and Long Inverse), Figure2.2 shows various inverse characteristics of induction disc relays.

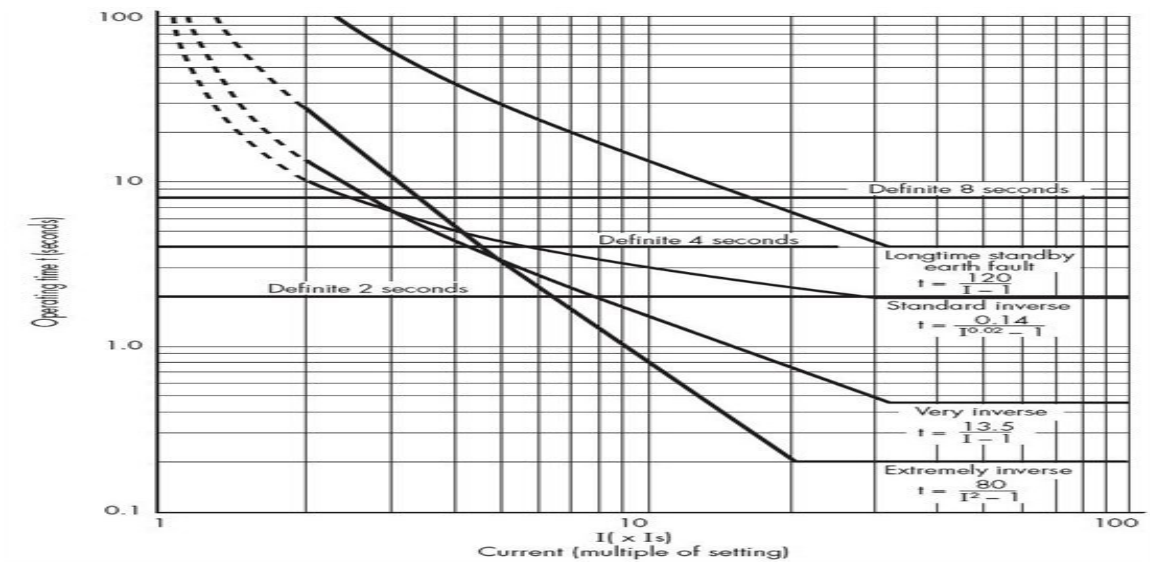

Figure 2.2: Various inverse characteristics of induction disc relays on log scale

For Normal inverse over current characteristics, the operation time is inversely proportional to the applied current. Very inverse over current characteristics are particularly suitable if there is a substantial reduction of fault current. The characteristics of this relay are such that its operating time is approximately doubled for a reduction in current from 7 to 4 times the relay current setting. This permits the use of the same time multiplier setting for several relays in series. For Extremely inverse over current characteristics, the operation time is approximately inversely proportional to the square of the applied current.[4]

Formulae used to determine the operating time: -

$$\boldsymbol{t} = \frac{\boldsymbol{K * TMS}}{((\frac{\boldsymbol{If}}{\boldsymbol{Is}})^{\boldsymbol{\alpha}} - \mathbf{1})} \quad (2.1)$$

Where:

t= operating time in sec TMS= time Multiplier Setting(tms)

K, α, β= Curve constants refer to Table (2.1), k = I_f= fault current, I_s= set Current.

Table (2.1): Curve constants

Type of curve	α	K
Normally inverse	0.02	0.14
Very inverse	1.0	13.5
Extremely inverse	2.0	80.0
Long time inverse	1.0	120.0

For a given fault current, the operating time of IDMT relay is jointly determined by its plug and time multiplier settings. Thus, this type of relay is most suitable for proper coordination. Operating characteristics of this relay are usually given in the form of a curve with operating current of plug setting multiplier along the X axis and operating time plotting this curve is shownFig.2.3 Relays require a protection margin (with .25 second allowed between device curves to ensure no cascading) between device curves.

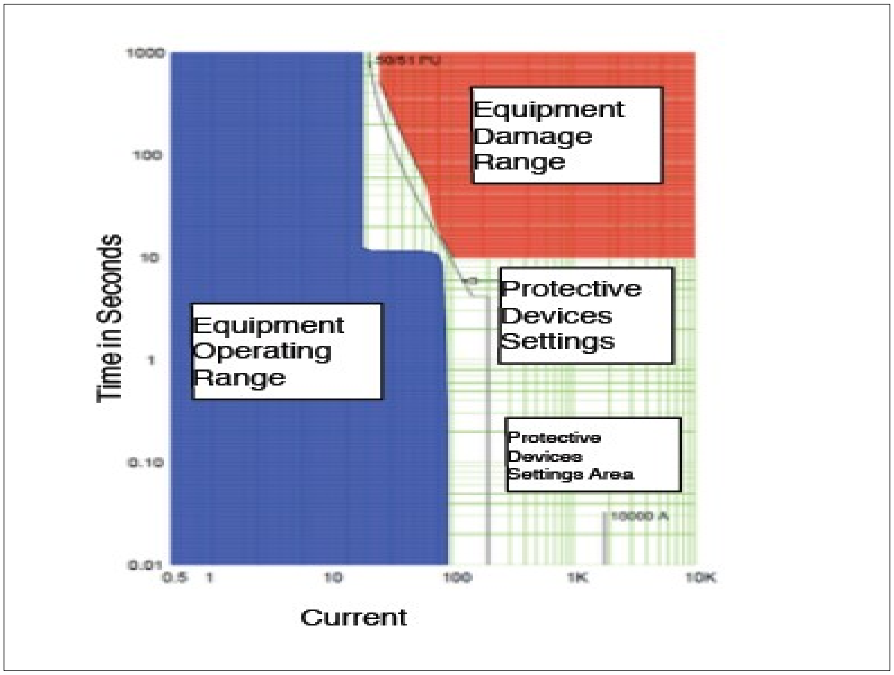

Figure2.3: Alog-log graph paper for plotting over current and earth curve

CHAPTER THREE

PROTECTION COORDNATION

3.1 The Importance of Coordination

A Coordination Study is critical for the safe, efficient, and economical operation of any electrical distribution system. Coordination Study will help to ensure that personnel and equipment are protected by establishing proper interrupting ratings.

When an electrical fault exceeds the interrupting rating of the protective device, the consequences can be devastating, including injury, damaged electrical equipment, and costly downtime. A Coordination Study maximizes power system selectivity by isolating faults to the nearest protective device, as well as helping to avoid nuisance operations that are due to transformer inrush or motor starting operations.

3.1.1 Selective Coordination

Selective coordination is often referred to simply as coordination. Coordination is defined in NEC® 240.2 as: "The proper localization of a fault condition to restrict outages to the equipment affected, accomplished by the choice of selective fault protective devices." It is important to note that the type of overcurrent protective device selected often determines if a system is selectively coordinated.

The figure below shows the difference between a system without selective coordination and a system with selective coordination. The figure on the left shows a system without selective coordination. In this system, unnecessary power loss to unaffected loads can occur, since the device nearest the fault cannot clear the fault before devices upstream open. The system on the right shows a selectively coordinated system. Here, the fault is cleared by the overcurrent device nearest the fault before any other upstream devices open, and unnecessary power loss to unaffected loads is avoided.

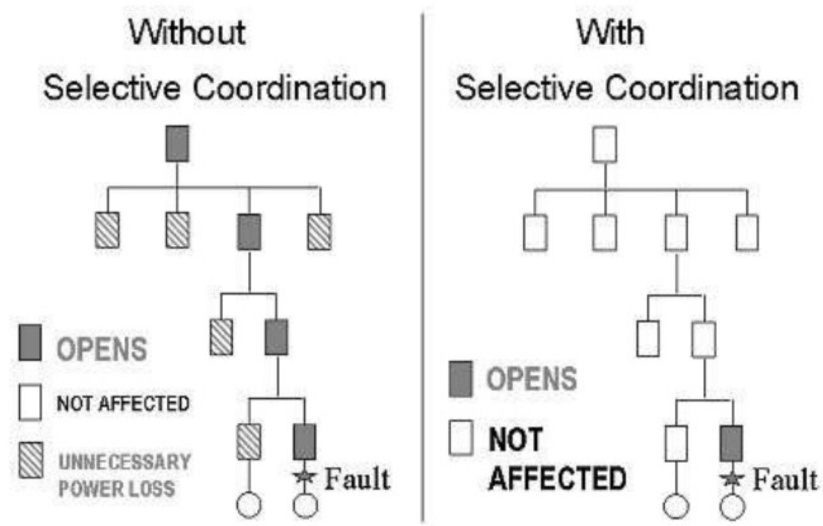

Figure 3.1: Selective coordination

3.2 Protective Device Coordination

Where there are two or more series protective devices between the fault point and the power supply, these devices must be coordinated to insure that the device nearest the fault point will operate first. The other upstream devices must be designed to operate in sequence to provide back-up protection, if any device fails to respond. This is called selective coordination. To meet this requirement, protective devices must be rated or set to operate on minimum overcurrent, in minimum time, and still be selective with other devices on the system. When the above objectives

are fulfilled, maximum protection to equipment, production, and personnel will be accomplished. As will be seen later in this chapter, protection and coordination are often in direct opposition with each other. Protection may have to be sacrificed for coordination, and vice versa. It is the responsibility of the electrical engineer to design for optimum coordination and protection.

3.3 The Coordination Study

A coordination study consists of the selection or setting of all series protective devices from the load upstream to the power supply. In selecting or setting these protective devices, a comparison is made of the operating times of all the devices in response to various levels of overcurrent. The objective, of course, is to design a selectively coordinated electrical power system. A new or revised coordination study should be made when the available short-circuit current from the power supply is increased; when new large loads are added or existing equipment is replaced with larger equipment; when a fault shuts down a large part of the system; or when protective devices are upgraded.

Time-current characteristic curves. Time is plotted on the vertical axis and current is plotted on the horizontal axis of all time -current characteristic curves. Log-log type graph paper is used to cover a wide range of times and currents. Characteristic curves are arranged so that the area below and to the left of the curves indicates points of "no operation," and the area above and to the right of the curves indicates points of "operation." The procedure involved in applying characteristic curves to a coordination study is to select or set the various protective devices so that the characteristic curves are located on a composite time-current graph from left to right with no overlapping of curves. The result is a set of coordinated curves on one composite time-current graph. The following data is required for a coordination study:

* Single-line diagram of the system under study.

* System voltage levels.

* Incoming power supply data.

* Impedance and MVA data.

* X/R ratio.

* Existing protection including relay device numbers and settings, CT ratios, and time-current characteristic curves.

* Generator ratings and impedance data.

* Transformer ratings and impedance data.

* Data on system under study.

* Transformer ratings and impedance data.

* Motor ratings and impedance data.

* Protective devices ratings including momentary and interrupting duty as applicable.

* Time-current characteristic curves for protective devices.

* CT ratios, excitation curves, and winding resistance.

* Thermal (I-t) curves for cables and rotating machines.

* Conductor sizes and approximate lengths.

* Short-circuit and load current data.

* Maximum and minimum momentary (first cycle) short-circuit currents at major buses.

* Maximum and minimum interrupting duty (5 cycles and above) short-circuit currents at major buses. The exact value of ground- fault current (especially arcing ground-fault current) is impossible to calculate. Methods are available for estimating ground-fault current.

* Estimated maximum and minimum arcing and bolted ground- fault currents at major buses.

* Maximum load currents.

* Motor starting currents and starting times.

* Transformer protection points.

3.4 Coordination Procedures

The following procedure should be followed when conducting a coordination study:

* Select a convenient voltage base and convert all ampere values to this common base. Normally, the lowest system voltage will be chosen, but this may not always be the case.

* Indicate short-circuit currents on the horizontal axis of the log-log graph.

* Indicate largest (or worst case) load imparities on the horizontal axis. This isusually a motor and should include FLA and LRA values.

* Specify protection points. These include magnetizing inrush point and NFPA 70 limits for certain large transformers.

* Indicate protective relay pick-up ranges.

* Starting with the largest (or worst case) load at the lowest voltage level, plot the curve for this device on the extreme left side of the log-log graph.

Although the maximum short-circuit current on the system will establish the upper limit of curves plotted to the right of the first and succeeding devices, the number of curves plotted on a single sheet should be limited to about five to avoid confusion.

* Using the overlay principle, trace the curves for all protective devices on a composite graph, selecting ratings or settings that will provide over - current protection and ensure no overlapping of curves.

* Coordination time intervals. When plotting coordination curves, certain time intervals must be maintained between the curves of various protective devices in order to ensure correct sequential operation of the devices. These intervals are required because relays have over-travel and curve tolerances; certain fuses have damage characteristics; and circuit breakers have certain speeds of operation.

3.5 The goals of Coordination

1. Maximum sensitivity.

2. Maximum speed.

3. Maximum security.

4. Maximum selectivity

CHAPTER FOUR

CASE STUDY: ALJENAID SUBSTATION

4.1 Description:

Aljenaid substation has two main power transformers, two are rated as (110/33/11) KV, 100 MVA, fed from two lines 110 KV , and two 33kV outgoing feeders .

4.2 Information used to Perform the Study

- Protective device manufacture and type: AREVA\ P142.

Transformer MVA, impedance and connections and rating current is shown in Table 4.1

Table 4.1: rating, impedance and connections

	MVA	Impedance voltage	Connection
T1, T2	100	13.7%	Star/Star/delta

- Current Transformer (CT) ratios is shown in table (4.2):

Table 4.2: Current transformer (CT) ratios

	CT ratio
110 KV transmission feeders	1600/1
110 KV bus couplers	2000/1
110 KV (T1,T2) incoming feeder	600/1
33 KV (T1,T2) outgoing feeder	2000/1
33KV bus coupler	2000/1
33 KV outgoing feeders	600/1

The study for setting calculation used the information above and with ETAP software analysis used to plot the relay characteristics curves. I simulate a number of faults in different location at worst cases to obtain the optimum setting.

4.3 Over Current Calculations

By using ETAP software simulated a number of faults in different location at worst cases to obtain the optimum coordination, starting coordinate form outgoing feeder to upstream incomer. For every fault the relay employed at that location, i.e. the primary relay should operate firstly. In case of failure of primary relay, the other backup relays by delay time according to relay setting must take good action. For all transformers the pickup values are set according to winding current rating, and for transmission lines and outgoing feeders to the thermal capability current.

4.3.1 Three phase faults at 33kv feeder

Three phase faults was made at 33kV feeder Figure 4.1:

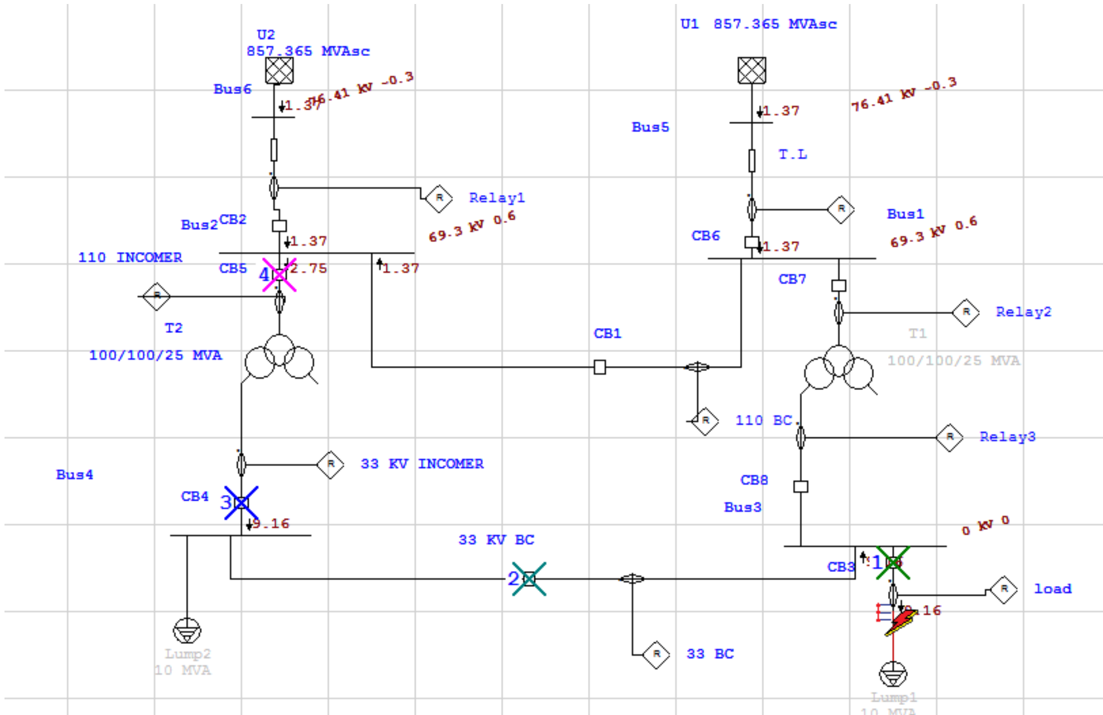

Figure 4.1: Three phase fault (9.16 KA) at 33kV Feeder

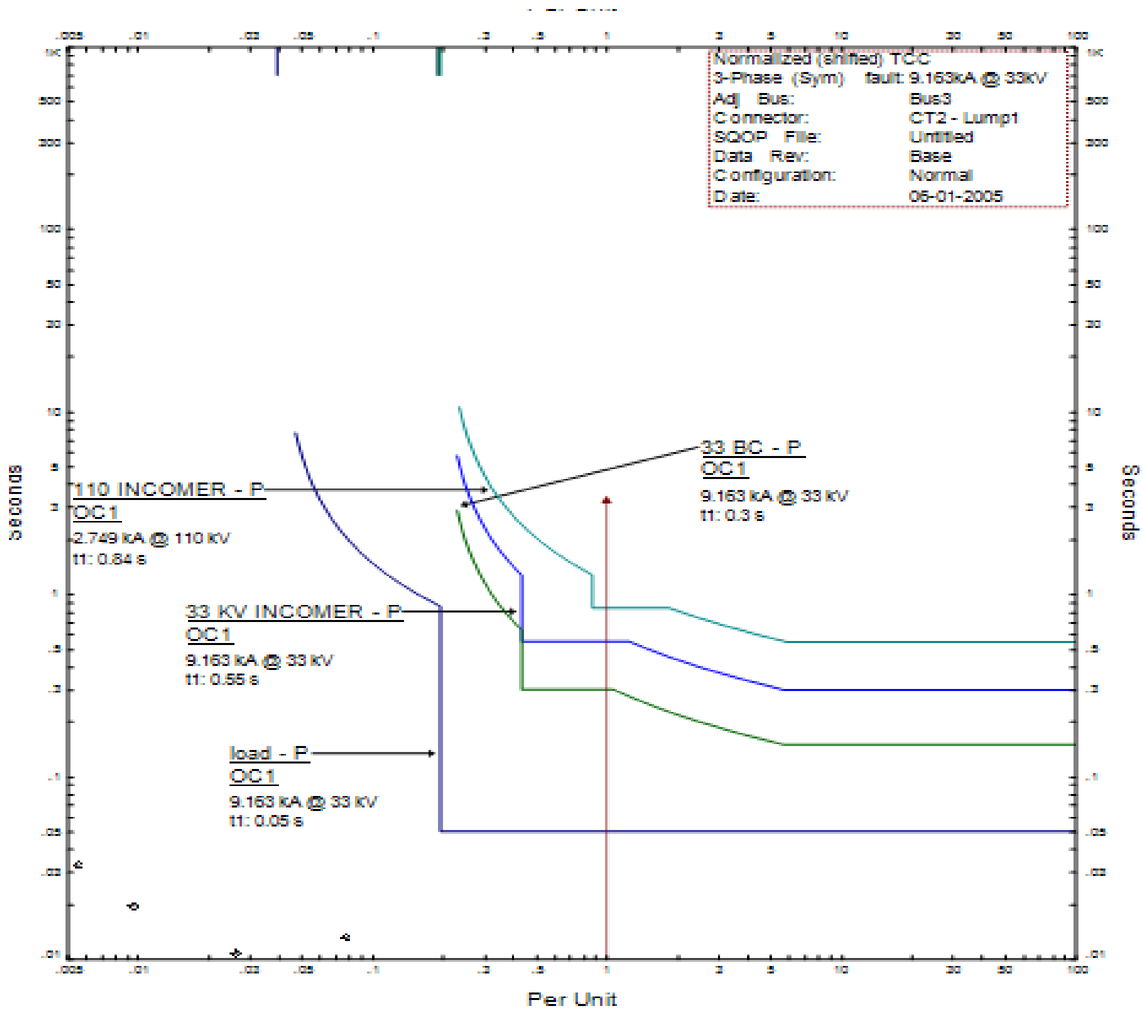

Figure 4.2: Coordination relay curves for a 9.16KA fault at 33KV outgoing feeder

4.3.2 Three phase faults at 33kv bus coupler

Three phase faults was made at 33kv bus coupler   Figure 4.3

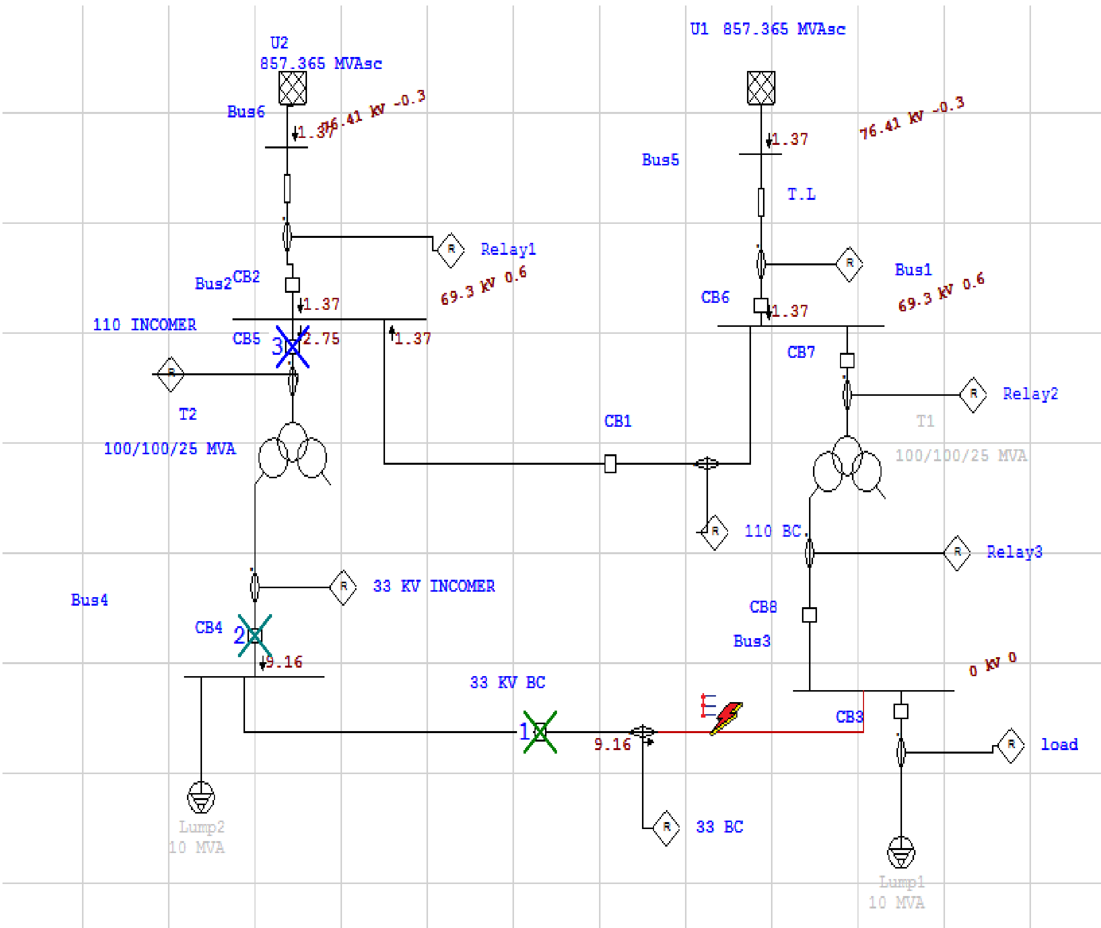

Figure 4.3: Three phase fault (9.16KA) at 33kV bus coupler

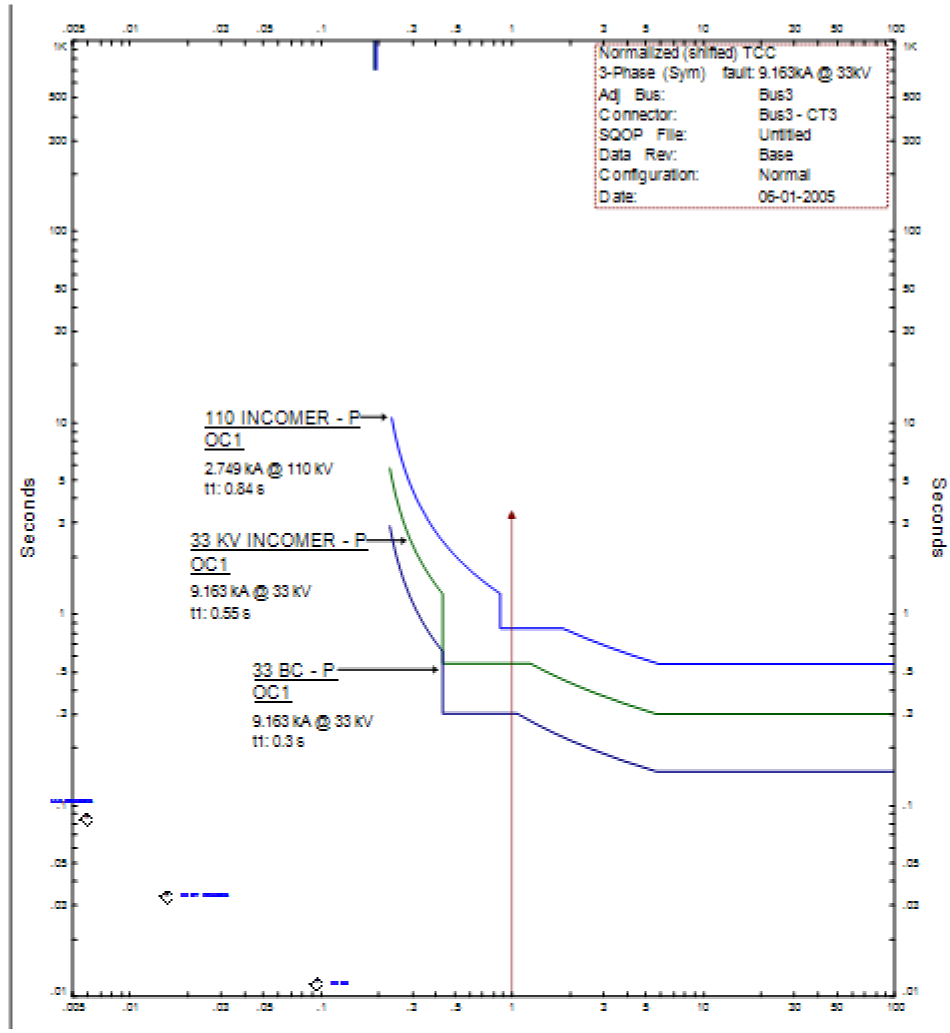

Figure 4.4: Coordination relay curves for a 9.16KA fault at 33KV bus coupler

4.3.3 Three phase fault at 33kV T2 incomer

Three phase fault was made at 33KV T2 Figure 4.5

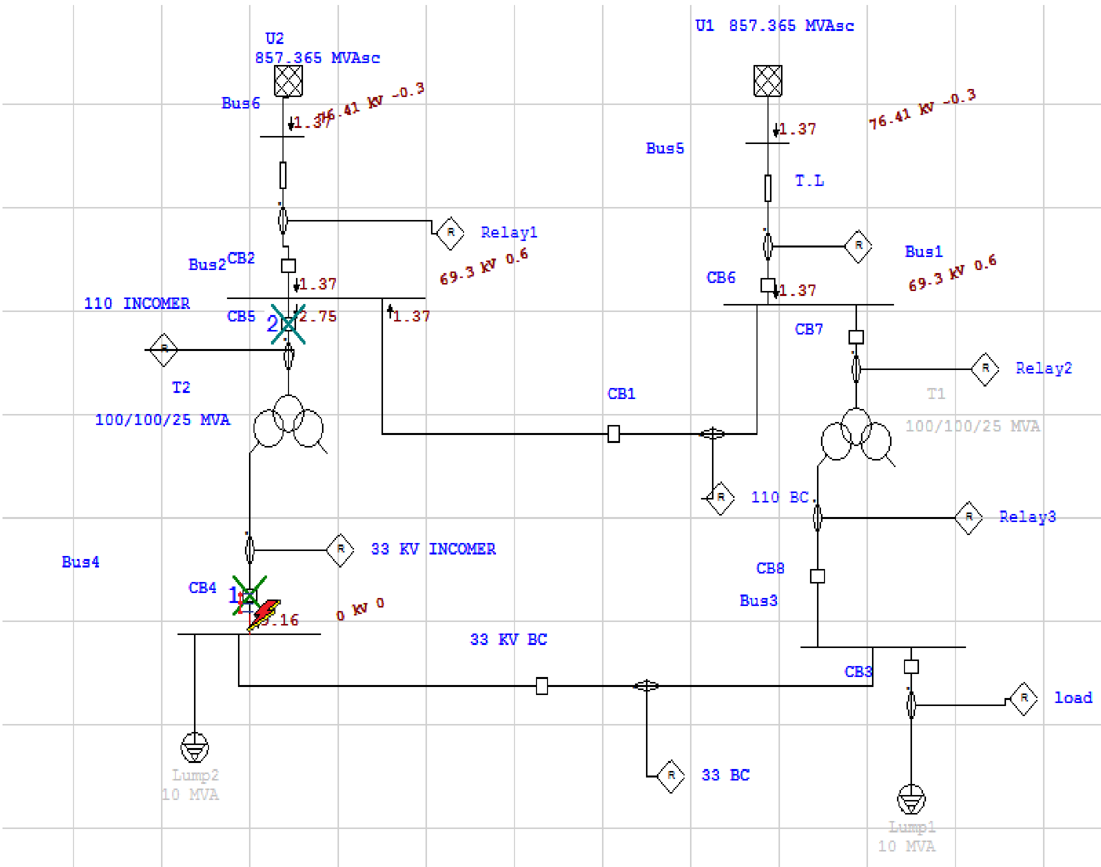

Figure 4.5: Three phase fault at 33kV T2 incomer

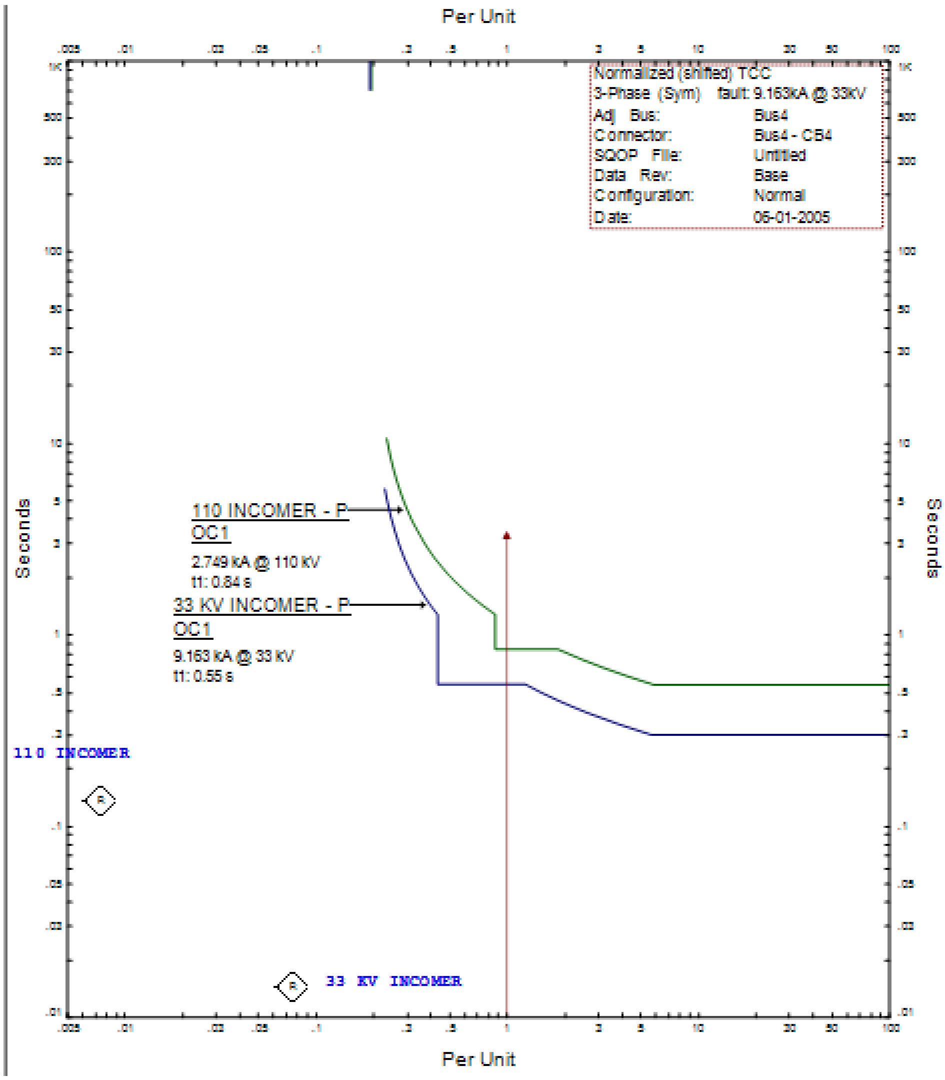

Figure 4.6: Coordination relay curves for a 9.16KA fault at 33kV T2 incomer

4.3.4 Three phase fault at 110kV T2 incomer

Three phase fault was made at 110 KV T2 Figure 4.7

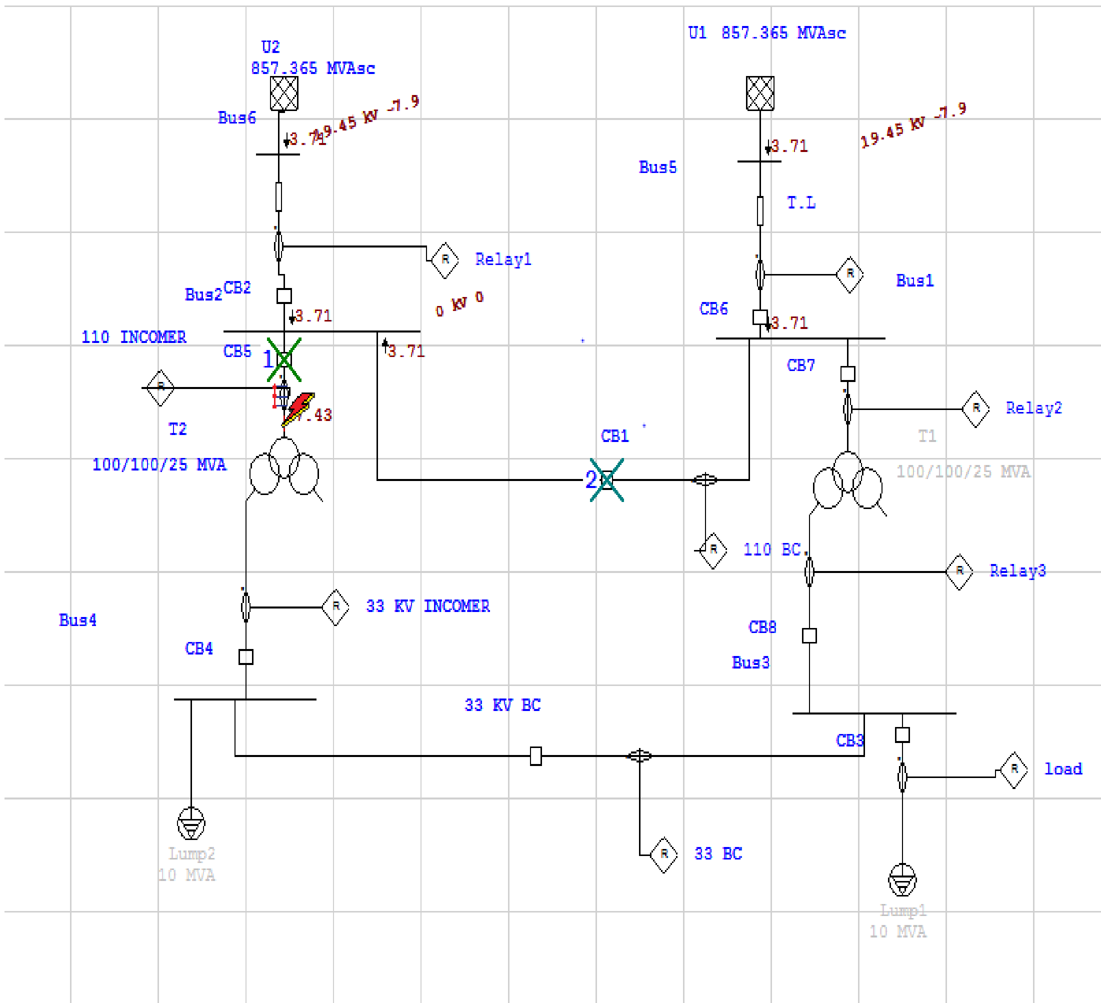

Figure 4.7: Three phase fault at 110kV T2 incomer

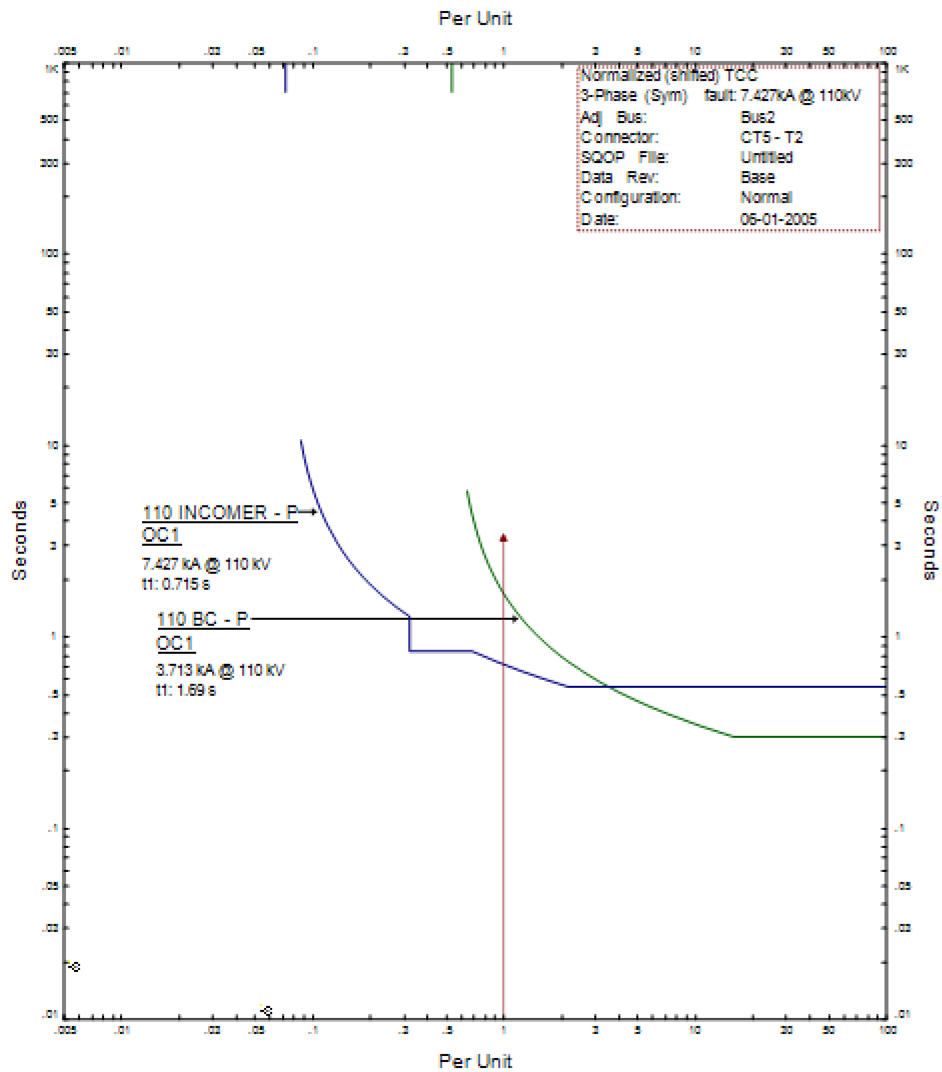

Figure 4.8:Coordination relay curves for a 7.43KA fault at 110kV T2 incomer

4.3.5 Three phase fault at transmission line

Three phase fault was made at transmission line Figure 4.9

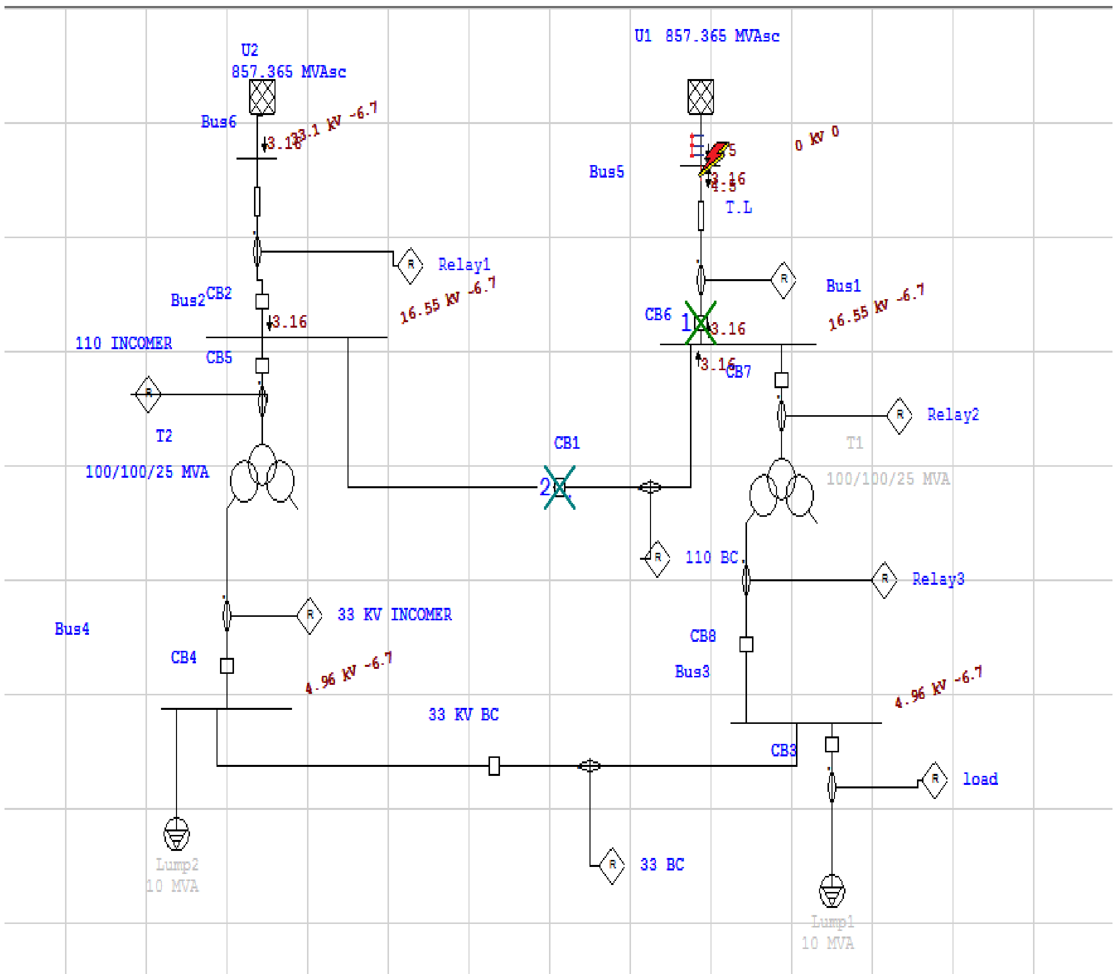

Figure 4.9: Three phase fault at transmission line

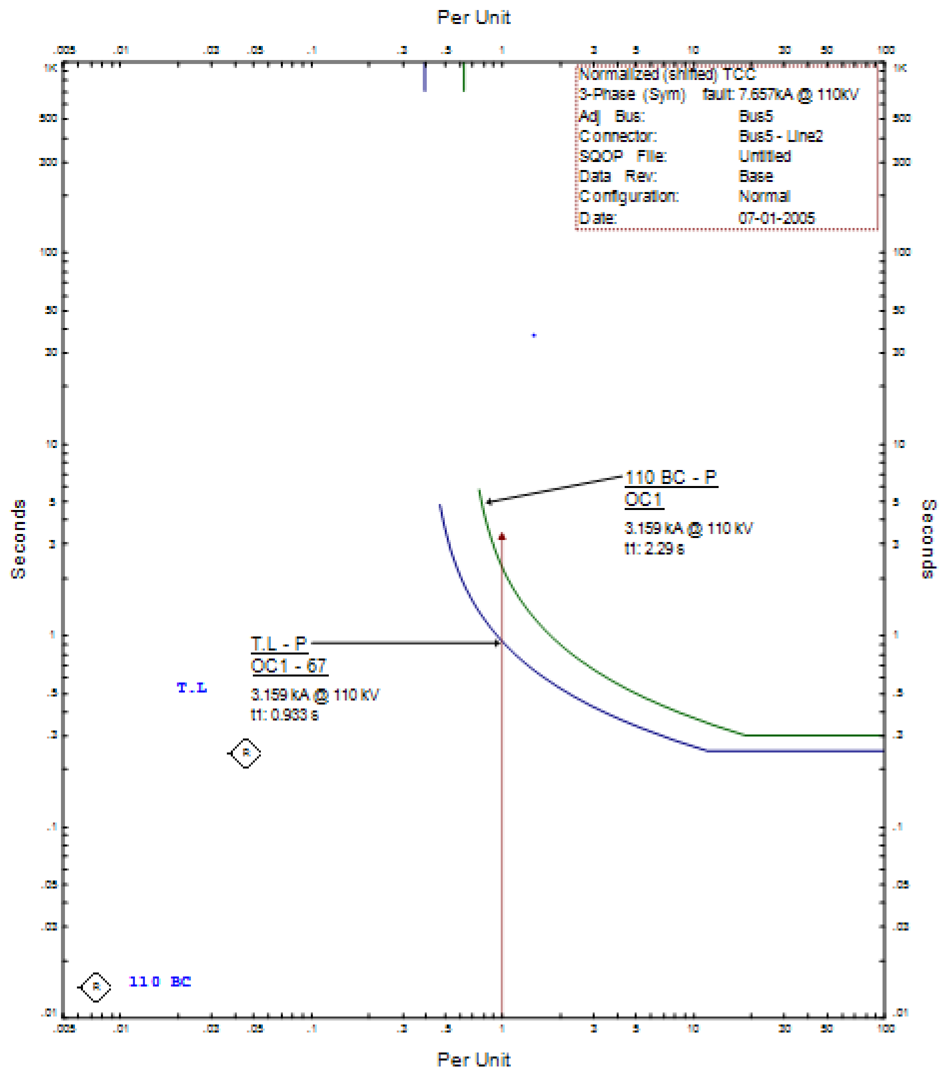

Figure 4.10:Coordination relay curves for fault at at transmission line

4.4 Earth |Fault Coordination

Like over current, I simulate a number of faults outside substation and inside the substation.

4.4.1 Single phase faults at 33kV feeder

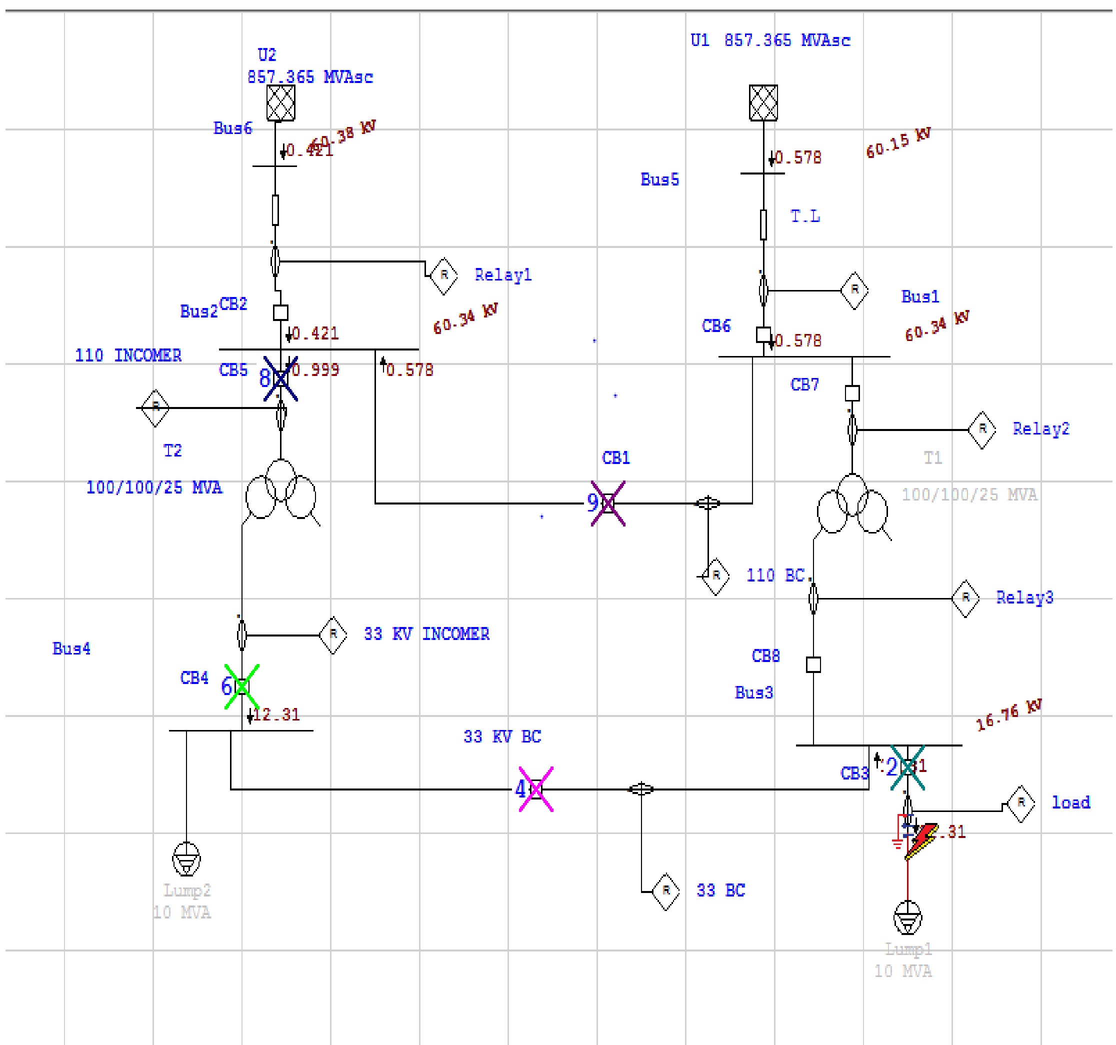

Figure 4.11:Earth fault at 33kV feeder

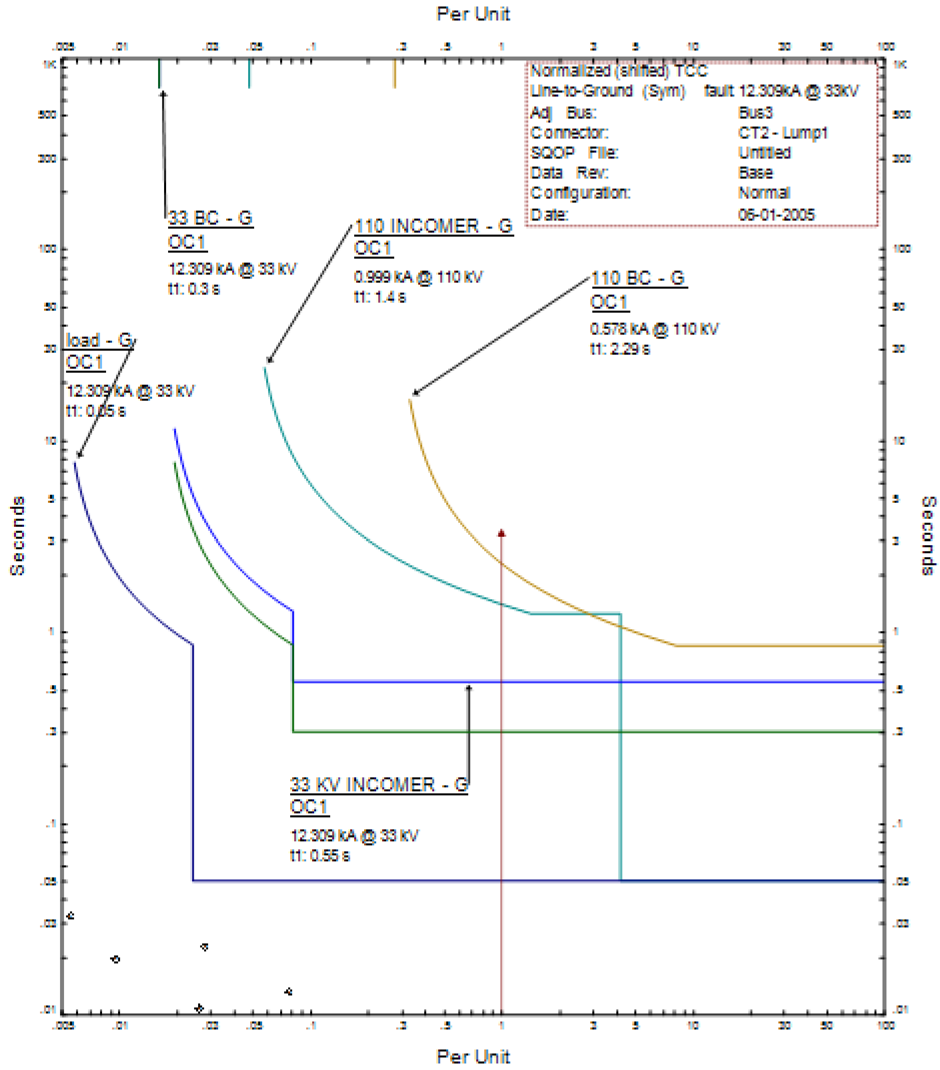

Figure 4.12: Coordination of the relays for 12.31KA at 33KV outgoing feeder single fault

4.4.2 Single phase faults at 33kv bus coupler

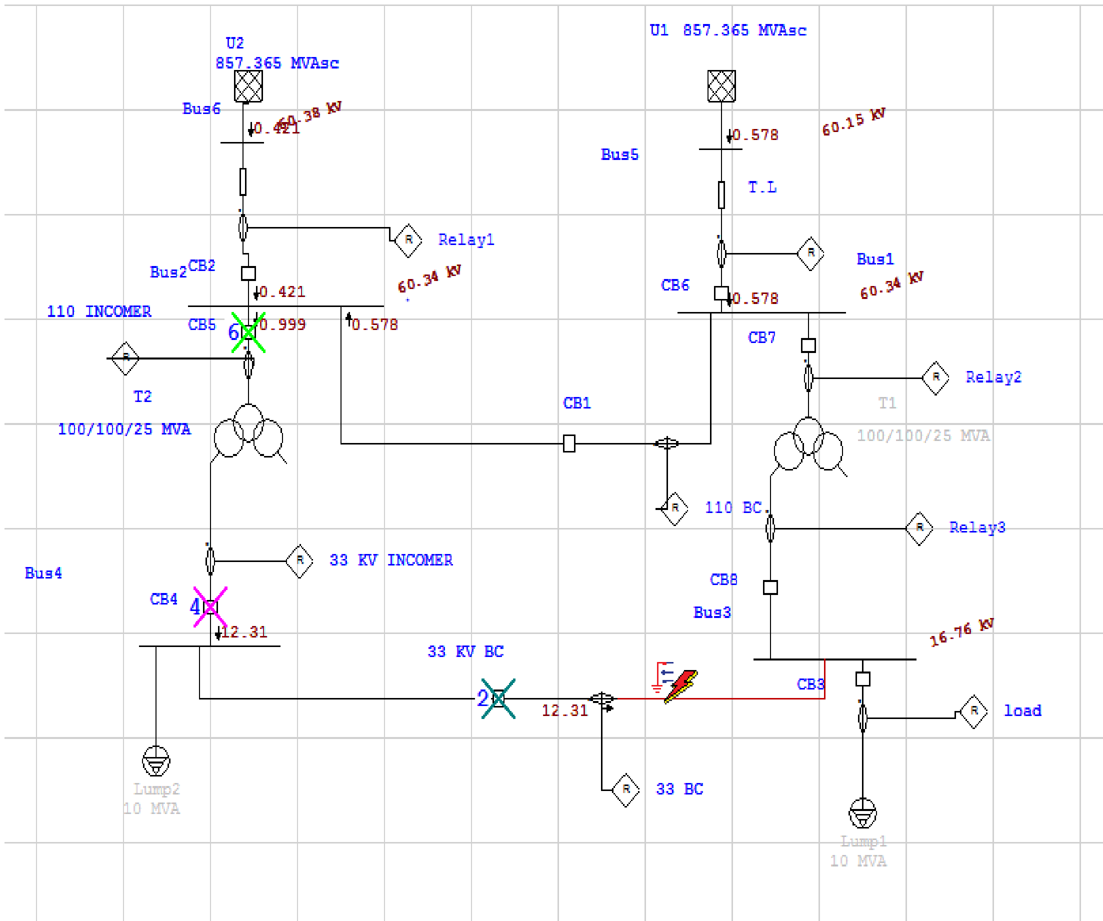

Figure 4.13:Earth fault at 33kV bus coupler

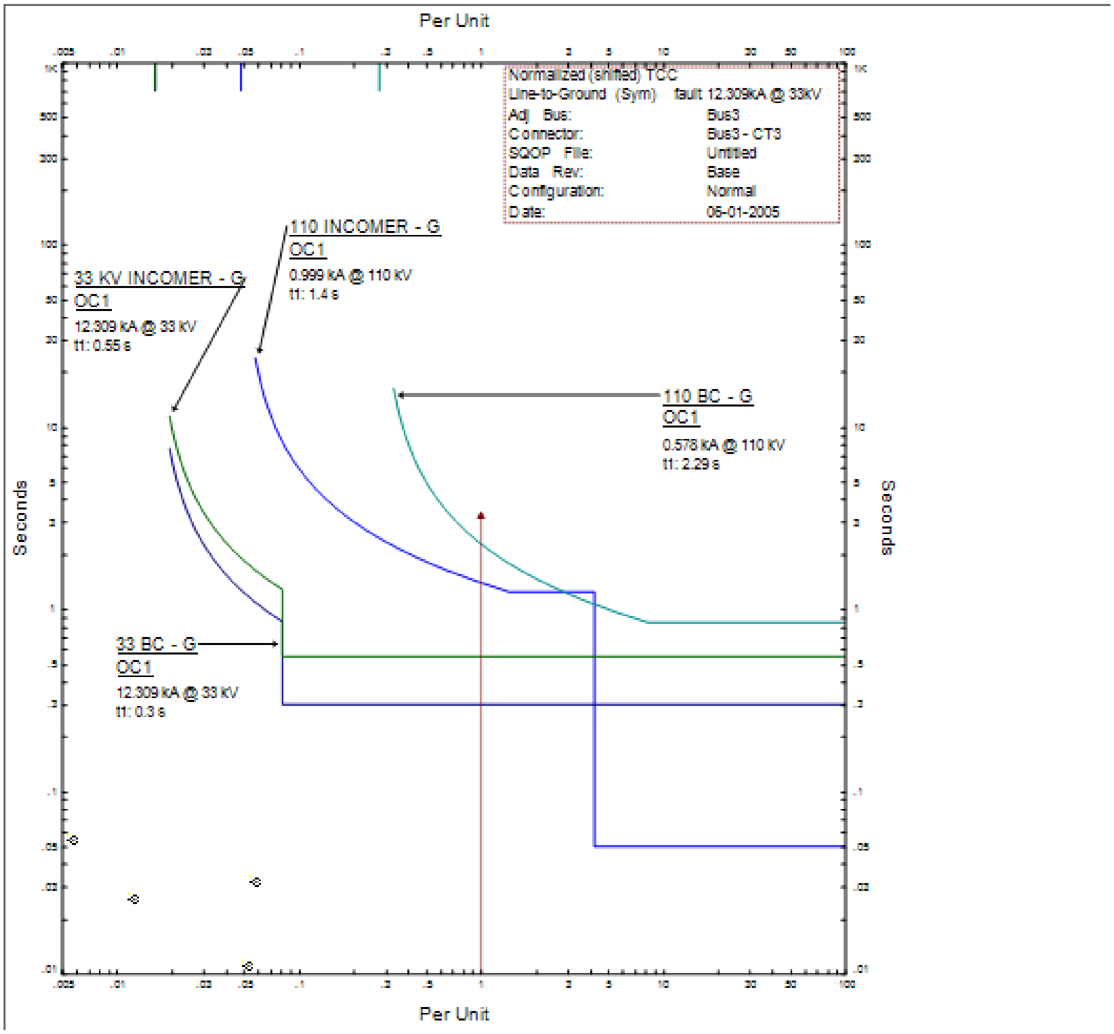

Figure 4.14: coordination of the relays for 12.31KA at 33KV bus coupler single fault

4.4.3 Single phase faults at 33 kV incomer T2

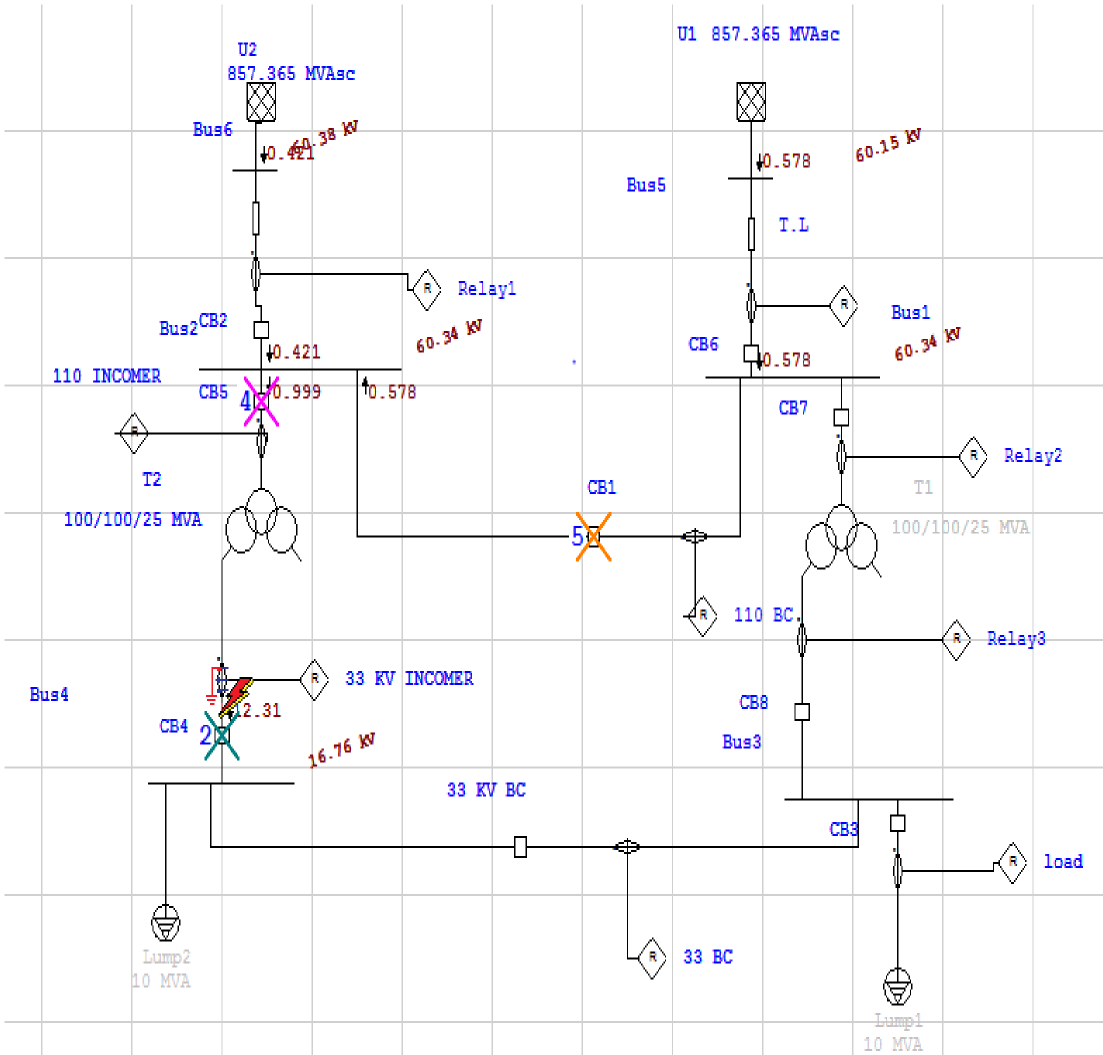

Figure 4.15: Single phase fault KA at 110kv incomer T2

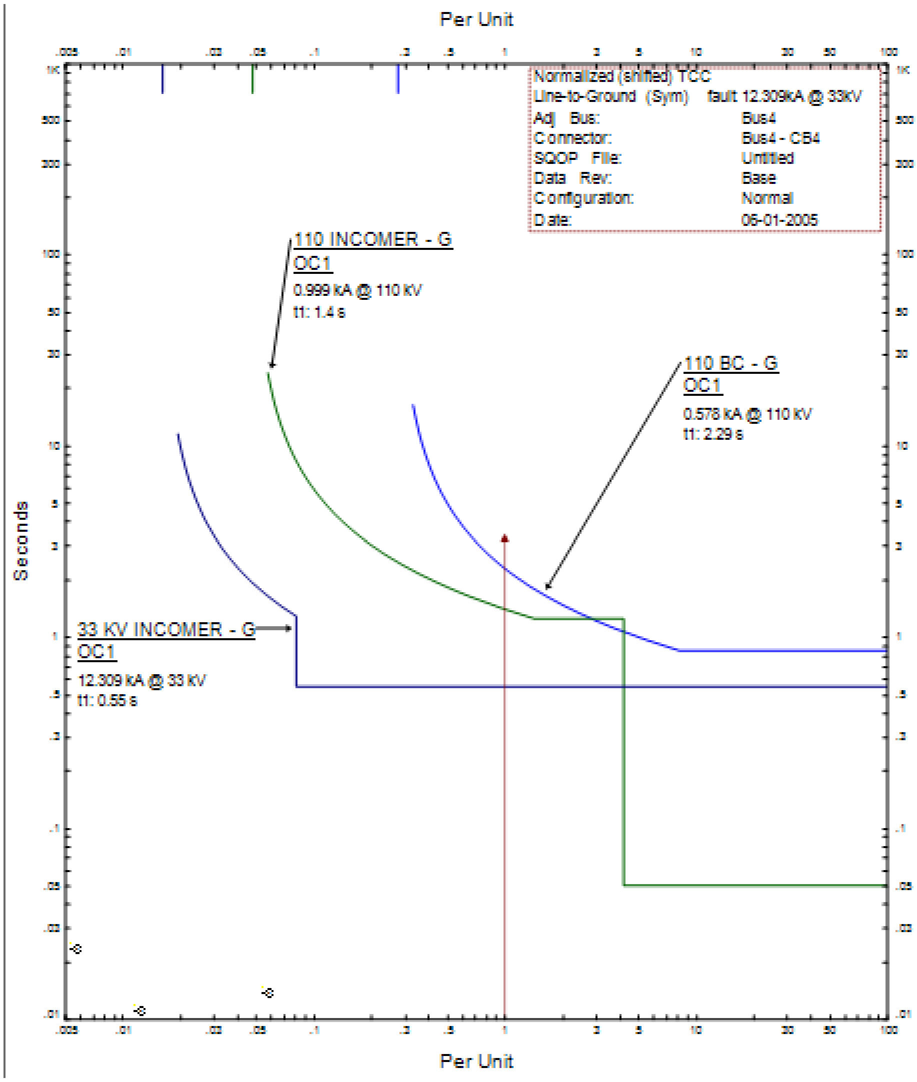

Figure 4.16: coordination of the relays at 33kV T2 single fault

4.4.4 Single phase faults at110 kV T2

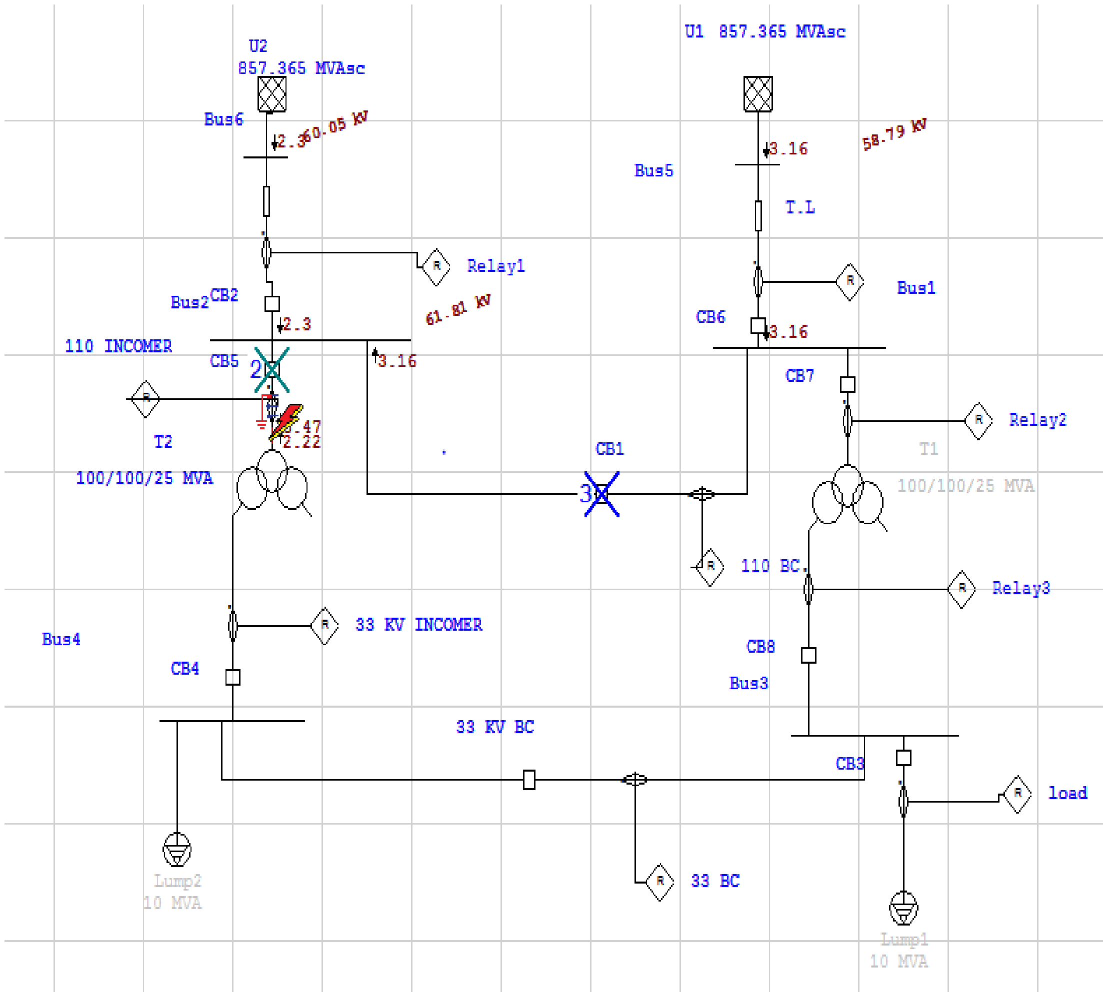

Figure 4.17: Single phase fault at 110kV incomer T2

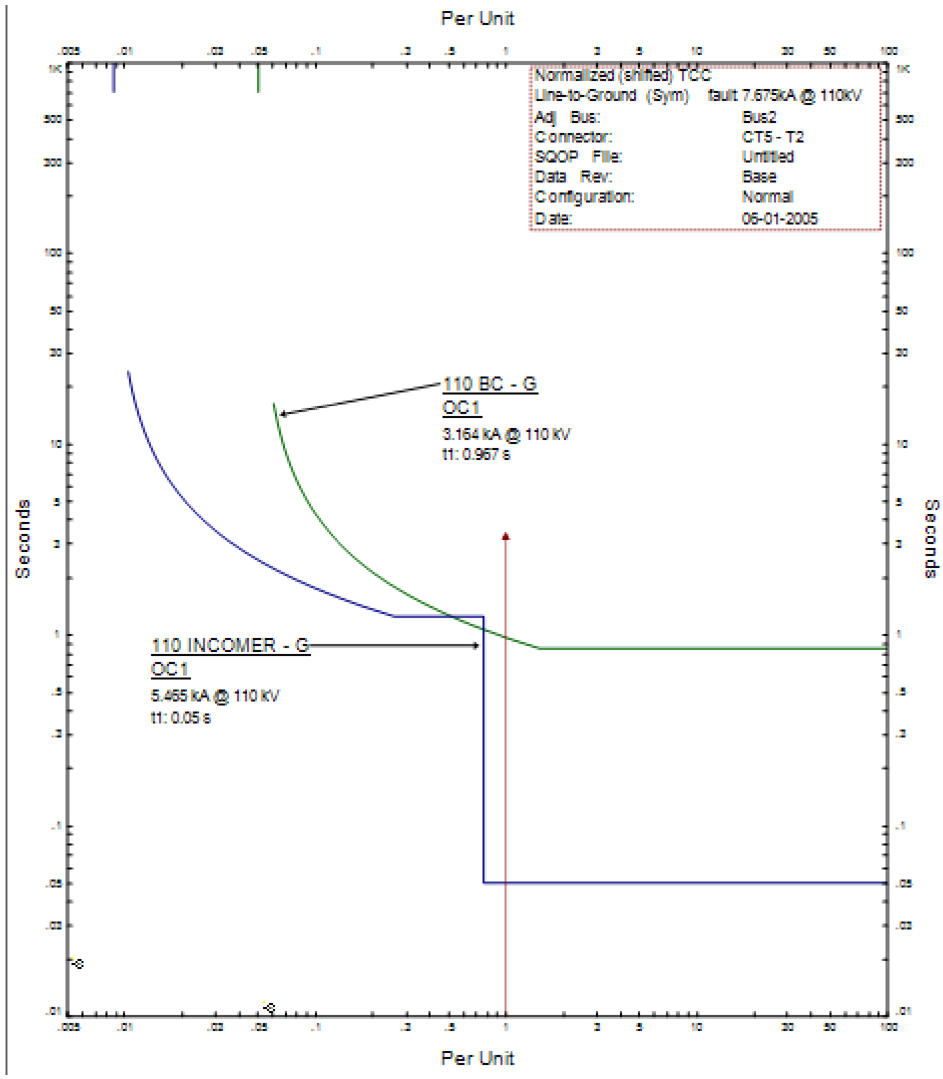

Figure 4.18: Single phase fault at 110kv incomer T2

4.4.5 Single phase faults at 110kv bus coupler

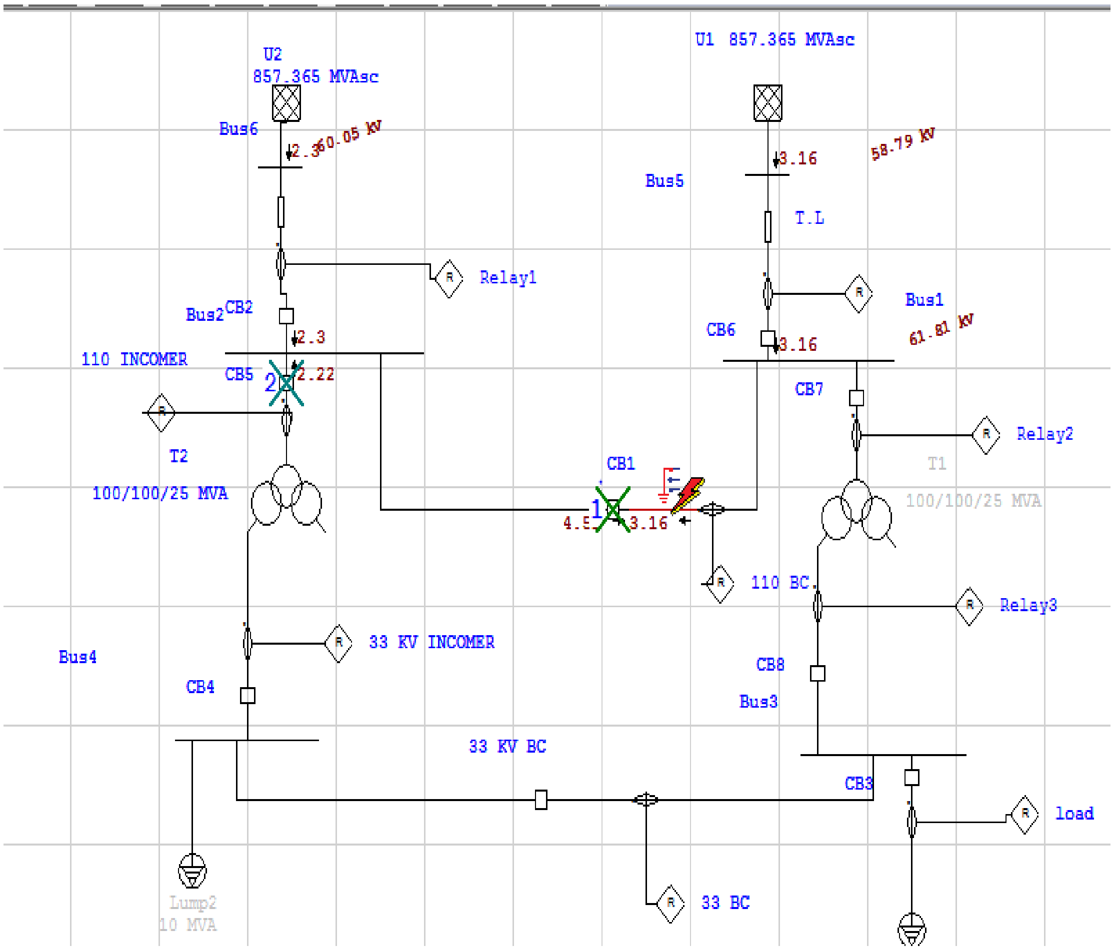

Figure 4.19:Earth fault at 110kV bus coupler

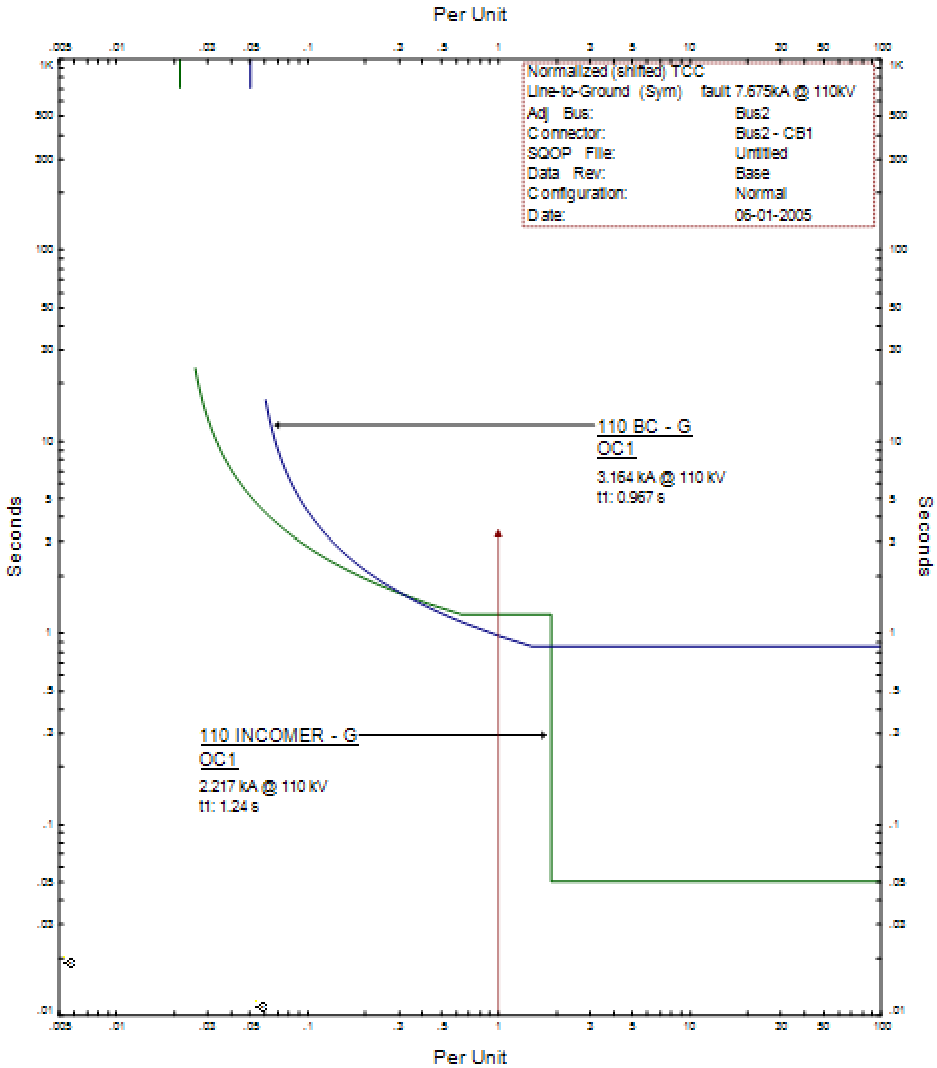

Figure 4.20:Earth fault at 110kV bus coupler

4.5 Simulation Results

From the previous simulation the following results were obtained.

4.5.1 Over current relays setting

Table 4.3 shows the coordination setting for over current fault.

Table 4.3: Over current setting

	CT Ratio	Current Setting(Is) Primary	Relay Characteristic	TMS(s)
33 KV Outgoing Feeder	600/1	360	S.I	0.2
33KV Bus Coupler	2000/1	1760	S.I	0.075
33 KV TR Incomer	2000/1	1760	S.I	0.15
110KV TR Incomer	600/1	540	S.I	0.275
110KV Bus Coupler	2000/1	2000	S.I	0.15
110KV Transmission Line .	1600/1	960	S.I	0.2

4.5.2 Earth fault relays setting

Table 4.4 shows the calculation setting for earth fault.

	CT Ratio	Current Setting(Is) Primary	Relay Characteristic	TMS(s)
33 KV Outgoing Feeder	600/1	60	S.I	0.2
33KV Bus Coupler	2000/1	200	S.I	0.2
33 KV TR Incomer	2000/1	200	S.I	0.3
110KV TR Incomer	600/1	48	S.I	0.625
110KV Bus Coupler	2000/1	160	S.I	0.425
110KV Transmission Line	1600/1	128	S.I	0.5

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The main objective of this thesis is fulfilled. In order to ensure the correct sequential operation of the protection devices when faults occurred ,ETAP software was used to make proper relays co-ordination for(Backup relays)for Aljenaid substation .The coordination is done by selecting the proper plug setting and time multiplication setting of the relays for different type of faults. After the plug setting and time multiplier setting is selected, the co-ordination is checked graphically, to ensure that certain time intervals must be maintained between the curves of various protective devices. The final results are listed in tables; in addition to that some recommendations are suggested for the future researchers.

5.2 Recommendations

The following recommendations can be given for the future researchers:

1. The review of Co-ordination is always essential since various additions, deletion of feeders and equipments will occur after the initial commissioning of plants.
2. Adding instantaneous stages for transformers incomer at:

   33KV at values below the maximum short levels to protect the winding of power transformers from high fault current that no need to delay the trip of circuit breakers because this type of faults is not detected by instantaneous primary protection (differential protection).

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