

**RECOMMENDED PROTECTION SCHEME SETTING COORDINATION FOR
NINE BUSBARS TRANSMISSION GRID**

RADHWAN MOHAMMED SALEEM

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**Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia**

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ABSTRACT

Protection system is one of the important parts of the power system. The protection system can be accepted if and only if it is efficient, reliable and realizes some requirements. For protection of transmission line three stepped distance protection can provide remote backup protection to transmission line by zone 2 and zone 3, but during the calculation of operation setting for different protection zones of the distance relays, some problems have been raised (overlap and under reach). These problems cause improper trips in the network. The aims at overcoming the problems are by taking into consideration the specifications of the adjacent transmission lines, the effect of arc resistance, earth resistance and the effect of remote infeed.

The line protection schemes are composed of distance relays and directional overcurrent relays where the setting of the relays must be computed considering both relays. Separate relay computation would lead to loss of selectivity. The standard IEC 60255 combined with the considerations of zone 2 tripping time have been used in order to overcome the coordination problems with the main protection (distance protection) as a local protection and to provide remote backup protection to the other overcurrent relays in the grid.

In this project, the protection of the transmission lines in typical IEEE, 9-busbars grid has been investigated in detail. The proper settings for both main protection (i.e. distance protection) and backup protection (i.e. overcurrent protection) devices have been determined. MATLAB and ETAP have been used as simulating tools to validate the protection settings techniques of the relays. Three approaches of settings have been used for the mentioned relays. The results show the proper settings of the both relays of the entire project.

ABSTRAK

Sistem perlindungan adalah salah satu daripada ciri-ciri penting dalam sistem kuasa. Sistem perlindungan ini boleh diguna pakai jika dan hanya jika sistem ini cekap, boleh dipercayai dan menepati syarat-syarat yang ditetapkan. Tiga peringkat jarak perlindungan bagi talian penghantaran boleh menghasilkan perlindungan jarak jauh sandaran kepada talian penghantaran oleh zon 2 dan zon 3, tetapi beberapa masalah telah timbul (bertindan dan dibawah jangkauan) sewaktu pengiraan penetapan operasi untuk zon perlindungan yang berbeza bagi geganti jarak. Masalah ini menyebabkan *trip* yang tidak bersesuaian dalam rangkaian talian penghantaran. Matlamat untuk mengatasi masalah ini adalah dengan mengambil kira spesifikasi talian penghantaran bersebalahan, kesan rintangan arka, rintangan bumi dan kesan kemasukan jauh.

Skema perlindungan talian terdiri daripada jarak geganti dan geganti arah arus lebih dimana penetapan untuk geganti mestilah dikira dengan mengambil kira kedua-dua geganti. Pengiraan berasingan bagi geganti akan membawa kepada ketidakupayaan untuk memilih. Piawaian IEC 60255 telah digabungkan dengan pertimbangan masa *tripping* zone 2 untuk mengatasi masalah koordinasi dengan perlindungan utama (perlindungan jarak) sebagai perlindungan di kawasan tersebut dan untuk menyediakan perlindungan sandaran jauh kepada geganti arus lebih yang lain dalam grid.

Dalam projek ini, 9 jenis grid busbar yang biasa digunakan oleh IEEE telah dikaji dengan mendalam. Penetapan alat yang betul bagi kedua-dua perlindungan utama (cth. perlindungan jarak) dan perlindungan sandaran (cth. perlindungan arus lebih) telah dikenal pasti. MATLAB dan ETAP telah digunakan sebagai alat simulasi untuk mensahihkan teknik penetapan perlindungan bagi geganti. Tiga pendekatan bagi penetapan telah digunakan untuk geganti tersebut. Hasil kajian menunjukkan penetapan untuk kedua-dua geganti bagi keseluruhan projek.

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LIST OF SYMBOLS AND ABBREVIATIONS

CB	Circuit Breaker
CT	Current Transformer
I_a	Current of phase a
I_b	Current of phase b
I_c	Current of phase c
I_m	Magnetizing current
I_o	Zero-sequence current at the relay location
ID	Intelligent device
IDMT	Inverse Definite Minimum Time
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
j	Imaginary numbers unit
kA	Kiloamperes
kT	Voltage factor
kV	Kilovolts
l_{arc}	Length of arce

ms	Milliseconds
PSM	Plug Setting Multiplier
R	Resistance axis on impedance plane
R	Relay in grid
R_f	Arc-fault resistance
s	Second
TMS	Time Setting Multiplier
VT	Voltage Transformer
V_a	Voltage of phase a
V_{arc}	Arc voltage
V_b	Voltage of phase b
V_c	Voltage of phase c
V_k	Knee-point Voltage
V_n	Rated voltage
X	Reactance axis on impedance plane
Z	Zone

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Transmission lines are vital parts of the electrical transmissions system, as they provide the path to transfer power from the generation to the load. Transmission lines operate at voltage levels from 69 kV to 765 kV and are ideally tightly interconnected for a reliable operation. Faults in transmission lines cause a disruption of electricity supply, which will affect to the overall power system and lead to a wide scale of blackout. Actually about two thirds of faults in the power system occur on the transmission line networks [1].

The protection of the transmission line plays an important part in the power system reliability by detecting the presence of the disturbance on the transmission line, sending the command to open the circuit breakers at each end immediately and isolating only the faulted section, in order for the protection of the transmission line to be designed as primary (or 'main') (e.g. distance protection) and for the backup protection (e.g. over current protection) to operate in parallel [2].

This project focuses on the procedure scheme setting for the typical IEEE, 9 Bus bars transmission grid. Two different rules for distance relay settings and the coordination of the overcurrent as a backup protection for zone 2 of distance relay have been investigated in details using MATLAB and ETAP as assimilation tools to validate the protection settings of the protection relays. Distance relay has been constructed to detect and classify the fault condition that might occurred in the

transmission lines and send tripping to its own circuit breaker in order to isolate the faulted section from the rest of the system using MATLAB SIMULINK, beside that the overcurrent relay have been investigated using ETAP, Inverse Definite Minimum Time (IDMT) type of IEC 60255 characteristic have been used to determine the proper settings of the overcurrent relays as a backup local and remote protection, down to full protection coordination for the entire project.

The results showed the problems of overlap and under reach in distance zone 2 and zone 3 settings coordination due to the remote infeed and the differences in the impedances of the transmission lines which is related to the type of the transmission lines, beside that the affect of arc resistance and earth resistances on the distance relay ability to distinguish the high faults impedance. these three problem have been overcome in the recommended settings by including the affect of the impedance differences, remote infeed and arc resistance in the relays zones settings. In additional to, the unpredictable tripping for overcurrent relays with non-directional settings as well as the unjustified loss for the loads, on the contrary of directional settings which achieved satisfactory tripping to the circuit breakers with the required time.

1.2 Problem Statement

The improper relays setting led to uncontrolled faults and can cause service outage, as well as extensive equipment damage. For distance relay, there are many setting rules for calculating the setting values of the different protection zones. The overlap problems and under reach problem have been raised for most of these rules especially in the second and third protection zone [3], as well as the high resistance fault especially related to high impedance arcing fault making the relays face difficulties in detected the fault current due to the high impedance present in the current path. For overcurrent relays, the setting must be computed considering both relays (Distance and Overcurrent), Separate relay computation would lead to loss of selectivity [4].

1.3 Objectives of the Study

This project focuses on the following objectives:

- i) To analyze the power system properties (e.g. load flow and fault analysis) of the standard the IEEE 9 busbars transmission line system.
- ii) To apply the appropriate settings and coordination of the distance and over current protection relays on the mentioned lines using typical standard IRAQI Std. and the recommendations of IEEE, C37-113 [5].
- iii) To introduce the new improve setting and coordination of the case studies system.

1.4 Scope of Study

Project will be focused on relays setting coordination in typical IEEE 9 bus bars system. It will be involved in studying different settings of the distance and overcurrent relays and the coordination will be analysed by using technical programs MATLAB/SIMULINK and ETAP, the real system will be analysed in a healthy and faulty condition. From the analysis, the recommendation settings and coordination of the relays in the system will be developed.

1.5 Significance of study

The project presents the recommended protection settings calculation procedure for the protection relays (Distance and Overcurrent) to protect the 230 kV transmission lines by studying the network in a normal and abnormal condition and taking into consideration all the phenomena affecting the impedance measuring during several types of faults to enable the distance relay to cover all types of faults. The project

approach can be used as a standard design in protecting the transmission lines in any transmission grid.

1.6 Organizations of Thesis

This project is organized as follows:-

Chapter 1 covers the background of the study, problem statement, objective of the project, project scope, significance of project and expected results from the research and testing.

Chapter 2 presents the literature review of the previous case study on the setting calculations procedure and the components of the 230 kV grid and the technique of protection relays coordination and the types of faults in the transmission lines and the phenomena associated with it.

Chapter 3 deliberates on the methodology of works; start with simulating the IEEE 9 busbars with the ETAP program, deduce the load flow of the grid, deduce the short circuit analysis of the grid, calculate the settings for the relays, construct the distance relay by MATLAB Simulink and simulate the overcurrent relays by ETAP.

Chapter 4 reports and discusses on the results obtained from the test of the distance relay due to the simulation using MATLAB and the results obtained from the test of the overcurrent relays due to the simulation using ETAP. The results from the simulation were compared to identify the appropriate settings.

Chapter 5 will go through the conclusion and recommendation for future study. Reference cited and supporting appendices are given at the end of this report while the documentation CD is also available and attached on the back covers of this project report for future references.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter starts with literature review of previous case study on the procedure scheme setting for the transmission grid. Understanding aforementioned researchers are important as guidance for this study to move on. Literature review on protection 230 kV transmission line is discussed herein. More detailed information on distance protection device is also presented.

2.2 Faults Occurrences

The nature of a fault is simply defined as any abnormal condition, which causes a reduction in the basic insulation strength between phase conductors, or between phase conductors and earth or any earthed screens surrounding the conductors. In practice, a reduction is not regarded as a fault until it is detectable, that is until it results either in an excess current or in a reduction of the impedance between conductors, or between conductors and earth, to a value below that of the lowest load impedance normal to the circuit. Thus a higher degree of pollution on an insulator string, although it reduces the insulation strength of the affected phase, does not

become a fault until it causes a flashover across the string, which in turn produces excess current or other detectable abnormality, for example abnormal current in an arc-suppression coil. Following are some of the main causes:

2.2.1 Lightning

More than half of the electrical faults occurring on overhead power transmission lines are caused by lightning. The main conventional approaches for reduction of the lightning flashover faults on power lines are lowering of the footing resistance and employing of multiple shielding wires, and differential insulation.

2.2.2 Pollution

Pollution is commonly caused by deposited soot or cement dust in industrial areas, and by salt deposited by wind-borne sea-spray in coastal areas. A high degree of pollution on an insulator string, although it reduces the insulation strength of the affected phase, does not become a fault until it causes a flashover across the string, which in turn reduces excess current or other detectable abnormality, for example abnormal current in an arc-suppression coil.

2.2.3 Fires

The occurrence of fire under transmission lines is responsible for a great number of line outages in many countries. Faults are mainly due to conductor to ground short circuit at mid-span or phase-to-phase short circuit depending on line configuration and voltage level. To reduce these outages to a minimum, the clearance of existing lines must be increased in forests. Clearing and vegetation on the line right of way in

such areas is also a consideration. Another problem arising from burning is the contamination of the insulators due to the accumulation of particles (soot, dust) on its surfaces. In this case, the line insulation requirements should be determined in such a way that the outages under fire could be reduced to a minimum. [22] Other causes of faults on overhead lines are trees, birds, aircraft, fog, ice, snow loading, punctured or broken insulators, open-circuit conductors and abnormal loading.

2.3 Types of Faults

Power system faults may be categorized as shunt faults and series faults. The most occurring type of shunt faults is Single Line-to-ground faults (SLG), which one of the four types of shunt faults, which occur along the power lines. This type of fault occurs when one conductor falls to ground or contacts the neutral wire. It could also be the result of falling trees in a winter storm. The second most occurring type of shunt faults is the Line-to-Line fault (LL). It is the result of two conductors being short-circuited. As in the case of a large bird standing on one transmission line and touching the other, or if a tree branch fall on top of the two of the power lines. Third type of fault is the Double Line-to-Ground fault (DLG). This can be a result of a tree falling on two of the power lines, or other causes. The fourth and least occurring type of fault is the balanced three phase, which can occur by a contact between the three power lines in many different forms. Figure 2.1 show the mentioned types of faults.

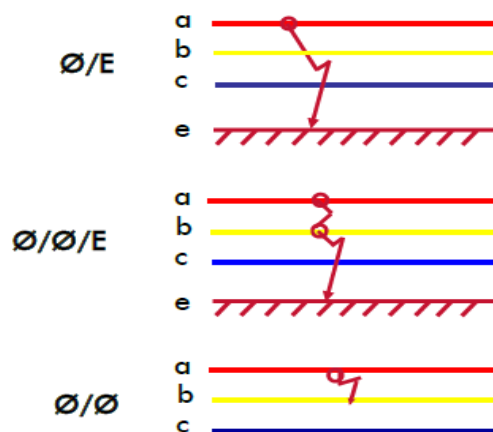


Figure 2.1: Types of transmission line faults [9]

2.4 Power System Protection

Power system protections are one of the electrical powers engineering that in the matter of electrical power systems from faults through the isolation of the faulted system from the healthy of the electrical network. To be said, it is very important system to protect humans or any components from gain any damage. System protections are used to detect and isolates the faulty system automatically.

Some abnormal conditions are often occurring in an interconnected system. For this reason, the damage of the equipment and the interruption of the supply connected to the power system could be happen.

2.5 Protection System Components

Generally protection system consist of three main components which are protection devices (relay), instrument transformers (CTs and VTs) and circuit breakers as shown in figure 2.2[6].

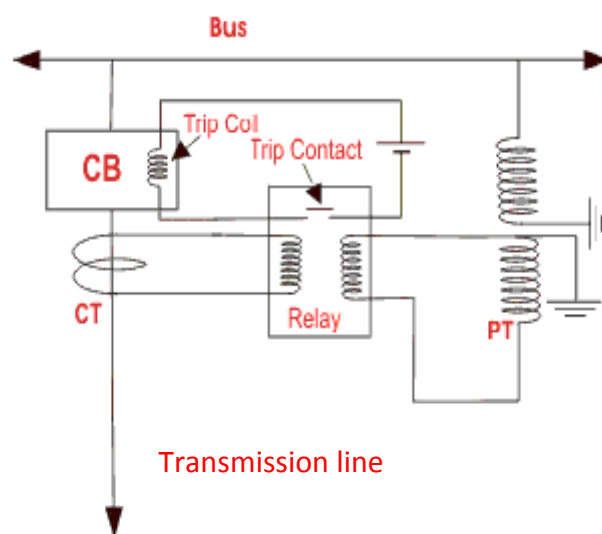


Figure 2.2: Power system protection components [6]

2.5.1 Current Transformers

They provide a current proportional to the current flowing through the primary circuit in order to perform energy metering or to analyze this current through a protection device. The secondary is connected to low impedance (used in practically short-circuited conditions). BS 3938 specifically defines current transformers designed for protection under the heading class X.

According to the British Standard, class X is defined by the rated secondary current, the minimum knee-point voltage, the maximum resistance of the secondary winding and the maximum magnetizing current at the rated knee-point voltage.

Rated knee-point voltage (V_K) at the rated frequency is the voltage value applied to the secondary terminals, which, when increased by 10%, causes a maximum increase of 50% in magnetizing current.

While the maximum resistance of the secondary winding (R_{ct}) is the maximum resistance of this winding, corrected at 75°C or at the maximum operating temperature if this is greater.

The maximum magnetizing current (I_m) is the value of the magnetizing current at the rated knee-point voltage, or at a specified percentage of this current as shown in figure 2.3 [7].

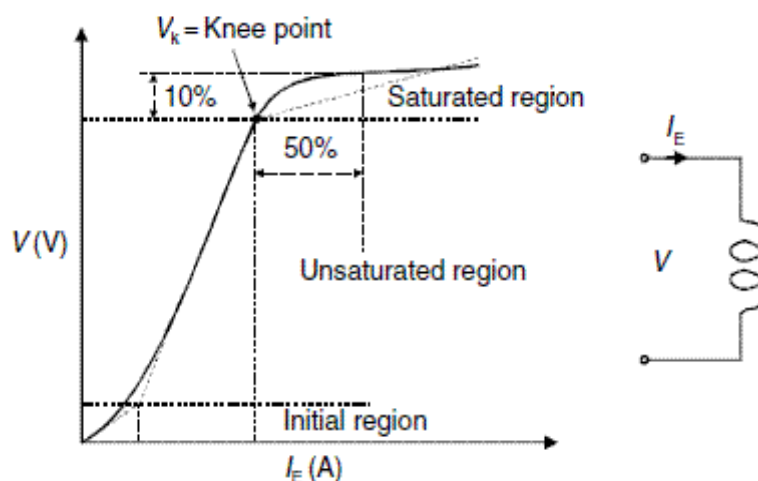


Figure 2.3: Knee-point voltage and magnetizing current of a CT according to BS [7]

2.5.2 Voltage Transformers

A voltage transformer is designed to give the secondary a voltage proportional to that applied to the primary. For a VT, the primary voltage/secondary voltage ratio is constant, the main two types are electromagnetic voltage transformer and capacitive voltage transformer which refer to internal construction. Voltage transformers used for protection in compliance with IEC 60044-2. The IEC accuracy classes are 3P and 6P. In practice, only class 3P is used. The accuracy class is guaranteed for the following values, voltages between 5% of the primary voltage and the maximum value of this voltage which is the product of the primary voltage and the rated voltage factor ($k_T \times V_n$) (see Table 1.2) and for a secondary load between 25% and 100% of the accuracy power with an inductive power factor of 0.8 [7].

Table 2.1 Maximum voltage and phase displacement errors in accordance with the accuracy class for protective VTs (U_n : rated voltage, k_T : voltage factor)

Accuracy class	Voltage error in $\pm\%$		Phase displacement in minutes	
	between 5% of U_n and $k_T \cdot U_n$	Between 2% and 5% of U_n	between 5% of U_n and $k_T \cdot U_n$	Between 2% and 5% of U_n
3P	3	6	120	240
6P	6	12	240	280

2.5.3 Protection Devices (Relays)

One of the important equipments in the protection of power system are protective relays. IEEE defined relay as “an electric device that designed to interpret input conditions in a prescribed manner, and after specified conditions are met to respond to cause contact operation or similar abrupt changes in associated electric control circuits [20]”. Thus the main function of protective relays is to separate a faulty area by controlling the circuit breaker with the least interruption to give service. The relay

is automatic devices to detect and to measure abnormal conditions of electrical circuit, and closes its contact with the system.

There are many types of relay can be used in protect transmission lines systems according to their characteristic, logic, actuating parameter and operation mechanism such as magnitude relay, instantaneous relay, differential relay, directional relay, and distance schemes[7].

2.5.4 Circuit Breaker.

The International Electro technical Commission (IEC) Standard IEC 60947-2 defines a circuit breaker as “a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit.

The protective relay detects and evaluates the fault and determines when the circuit should be opened. The circuit breaker functions under control of the relay, to open the circuit when required. A closed circuit breaker has sufficient energy to open its contacts stored in one form or another (generally a charged spring). When a protective relay signals to open the circuit, the store energy is released causing the circuit breaker to open. Except in special cases where the protective relays are mounted on the breaker, the connection between the relay and circuit breaker is by hard wiring. The important characteristics from a protection point of view are:

- i) The speed with which the main current is opened after a tripping impulse received.
- ii) The capacity of the circuit that the main contacts are capable of interrupting.

The first characteristic is referred to as the ‘tripping time’ and is expressed in cycles .Modern high-speed circuit breakers have tripping times between three and eight cycles.

The tripping or total clearing or break time is made up as follows:

- i) Opening time: The time between instant of application of tripping power to the instant of separation of the main contacts.
- ii) Arcing time: The time between the instant of separation of the main circuit breaker contacts to the instant of arc extinction of short-circuit current. Total break or clearing time: The sum of the above [7].

Figure 2.4 shows the simplified circuit diagram of trip circuit of a circuit breaker [7].

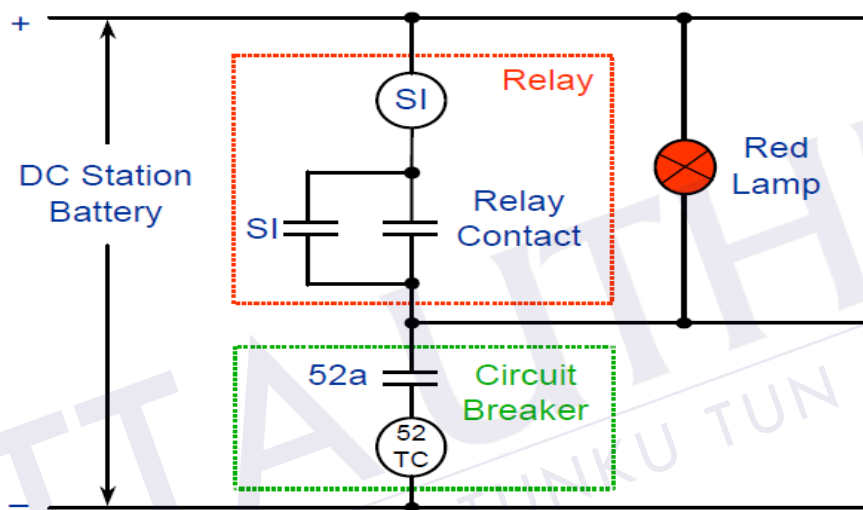


Figure 2.4: The trip circuit of a circuit breaker [7]

2.5.5 Tripping batteries

The operation of monitoring devices like relays and the tripping mechanisms of breakers require independent power source, which does not vary with the main source being monitored. Batteries provide this power and hence they form an important role in protection circuits. The relay/circuit breaker combination depends entirely on the tripping battery for successful operation. Without this, relays and breakers will not operate, becoming 'solid', making their capital investment very useless and the performance of the whole network unacceptable. It is therefore necessary to ensure that batteries and chargers are regularly inspected and maintained

at the highest possible level of efficiency at all times to enable correct operation of relays at the correct time [7].

2.6 Zones of Protection

Protection is arranged in zone in order to limit the broadness of the power system which is disconnected when a fault occurs. The protection zones overlap around circuit breakers. The purpose is to make certain that no section of the system is left unprotected .

Back-up protection is provided to ensure that the faulted element of the system is disconnected even if the primary protection fails to isolate the faulted element. Back-up protection can be provided locally or from a remote location. Local back-up protection is provided by equipment that is in addition to the equipment provided for primary protection whereas remote back-up protection is provided by equipment that is physically located at substations away from the location where equipment for primary.

The protection system zones as shown in Figure 2.5 are consists of generator, transformer, buses, transmission line and motor [9].

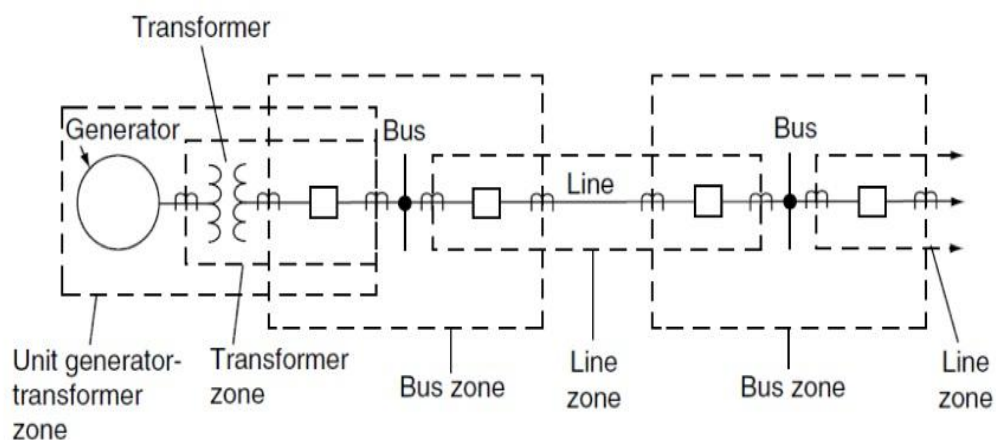


Figure 2.5: Protection system zones (Primary and Backup protection) [9]

2.7 Protection of Transmission Lines.

The protection of transmission lines consists of main (or primary) and backup protection (in order to provide high power system reliability) which are worked in parallel. In the event of failure or non-availability of the primary protection some other means of ensuring that the fault is isolated must be provided. These secondary systems are referred to as 'back-up protection. Remote back-up protection is provided by protection that detects an un-cleared primary system fault at a remote location and then issues a local trip command, e.g. the second or third zones of a distance relay. In both cases the main and back-up protection systems detect a fault simultaneously, operation of the back-up protection being delayed to ensure that the primary protection clears the fault if possible. Normally being unit protection, operation of the primary protection will be fast and will result in the minimum amount of the power system being disconnected. Operation of the back-up protection will be, of necessity, slower and will result in a greater proportion of the primary system being lost. [7].

2.8 Distance protection.

Distance protection has been widely used for protecting transmission and sub-transmission lines because of its simplicity, economy, suitability, and reliability. The basic principle of distance protection involves the division of the voltage at the relaying point by the measured current. The apparent impedance so calculated is compared with the reach point impedance. If the measured impedance is less than the reach point impedance, it is assumed that a fault exists on the line between the relay and the reach point. The calculated apparent impedance is compared with predetermined impedance is called reach of the relay. The apparent impedance is must larger than the impedance of reach of the relay during normal operation. However, if the fault occurs, the apparent impedance is less than the impedance-reach so relay will send a trip signal to the breaker.

2.8.1 Zones of Distance Protection.

A distance relay will have instantaneous directional zone 1 protection and one or more time delayed zones as shown in Figure 2.6 [9]. The tripping signal produced by zone 1 is instantaneous as it should not reach as far as the bus bar at the end of the first line so it is set to cover only 80-85 percent of the protected line. As for the other zones, they act as a back-up of the first zone making there is delay in seconds within those zones.

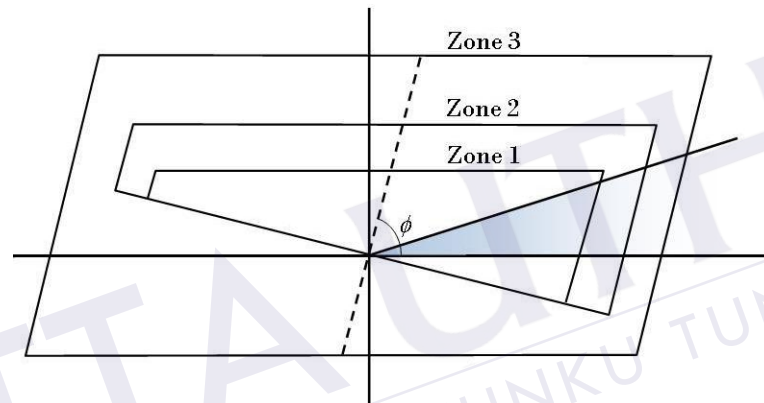


Figure 2.6: Zones of Protection of Distance Relay [9]

There are many setting rules for the distance relay in order to calculate the setting values of the different protection zones for the power system transmission lines are shown in figure 2.7 and table 2.1. The overlap problems have been raised for most of these rules especially in the third protection zone. [3]

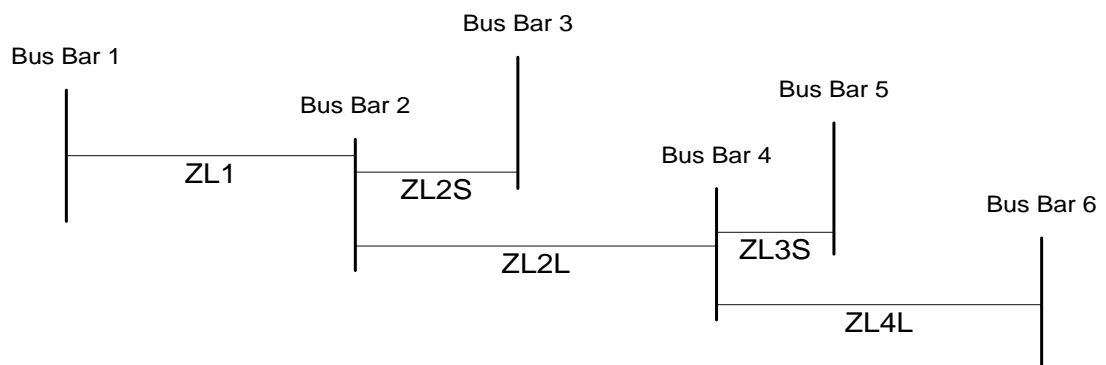


Figure 2.7: Transmission lines layout [3]

Table 2.2: Zones Setting Calculation

Zones Rules	Zone 1	Zone 2	Zone 3
1	$(80\% \text{ to } 85\%) Z_{L1}$	$Z_{L1}+50\% Z_{L2S}$	$Z_{L1}+Z_{L2L}+25\% Z_{L3S}$
2	$(80\% \text{ to } 90\%) Z_{L1}$	$(120\% \text{ to } 150\%) Z_{L1}$	$Z_{L1} + (120\% \text{ to } 180\%) Z_{L2}$
3	$85\% Z_{L1}$	$85\% (Z_{L1}+85\% Z_{L2})$	$85\% (Z_{L1}+85\% (Z_{L2}+85\% Z_{L3}))$
4	$80\% Z_{L1}$	$Z_{L1}+50\% Z_{L2S}$	$120\% (Z_{L1}+Z_{L2L})$
5	$80\% Z_{L1}$	$Z_{L1}+25\% Z_{L2S}$	$Z_{L1}+Z_{L2L}+25\% Z_{L3L}$

Where:

Z_{L1} : The impedance of the protected line.

Z_{L2} : The impedance of the second line.

Z_{L3} : The impedance of the third line.

Z_{L2S} : The impedance of the second shortest line.

Z_{L2L} : The impedance of the second longest line.

Z_{L3S} : The impedance of the third shortest line.

Z_{L3L} : The impedance of the third longest line.

The select of the rule must be examined to avoid overlapping between the relays in the network.

2.8.2 Iraqi standard specification (distance zones configurations)

This standard describes the functional performance requirements of the protection system to be supplied. For lines overhead line feeders phase-fault and earth-fault distance (main protection) protection have used permissive under reach transfer trip and for zone measuring elements setting have calculated In according to the following conditions [4]:

- (i) A setting ranges for the zone 1 the impedance measuring element of 50% to 120 % of line length on all protected lines.
- (ii) A setting capability for zone 2 overreaches protection to give typically 125% of each line length with a time delay in the range 0.2-1.5 seconds.
- (iii) Zone 3 protection time delay range of 0.8-3.0 seconds with a setting range to cover at least 200% of the protected line length, but with extended Zone 3 reach where long lines follow short lines.

2.8.3 Arc Resistance

The arcing fault can occur at many locations such as circuit breaker, switch board panel, low voltage distribution board, electrical appliances and overhead lines. As for overhead lines, the most common fault relating to the existence of arc is single line to ground fault. This type of fault especially related to high impedance arcing fault making the conventional relay face difficulties in detected the fault current due to the high impedance present in the current path. However, in order to overcome this problem the arc resistance can be added to zone measuring elements setting by calculate its value [10]. The following equations used to calculate arc resistance during the fault.

$$V_{arc} = 2500 * l_{arc} \quad (2.1)$$

$$R_{arc} = V_{arc}/I_{arc} \quad (2.2)$$

Where

V_{arc} : The arc voltage

R_{arc} : The arc resistance

l_{arc} : The length of the arc

2.8.4 Effect of Remote Infeed

A distance relay is said to under-reach when the impedance presented to it is apparently greater than the impedance to the fault. Percentage under-reach is defined as [8]:

$$\frac{Z_R - Z_F}{Z_R} * 100\% \quad (2.3)$$

Where

Z_R is the intended relay reach (relay reach settings)

Z_F is the effective reach

The main cause of under reaching is the effect of fault current infeed at remote busbars. This is best illustrated by a figure 2.8 [9].

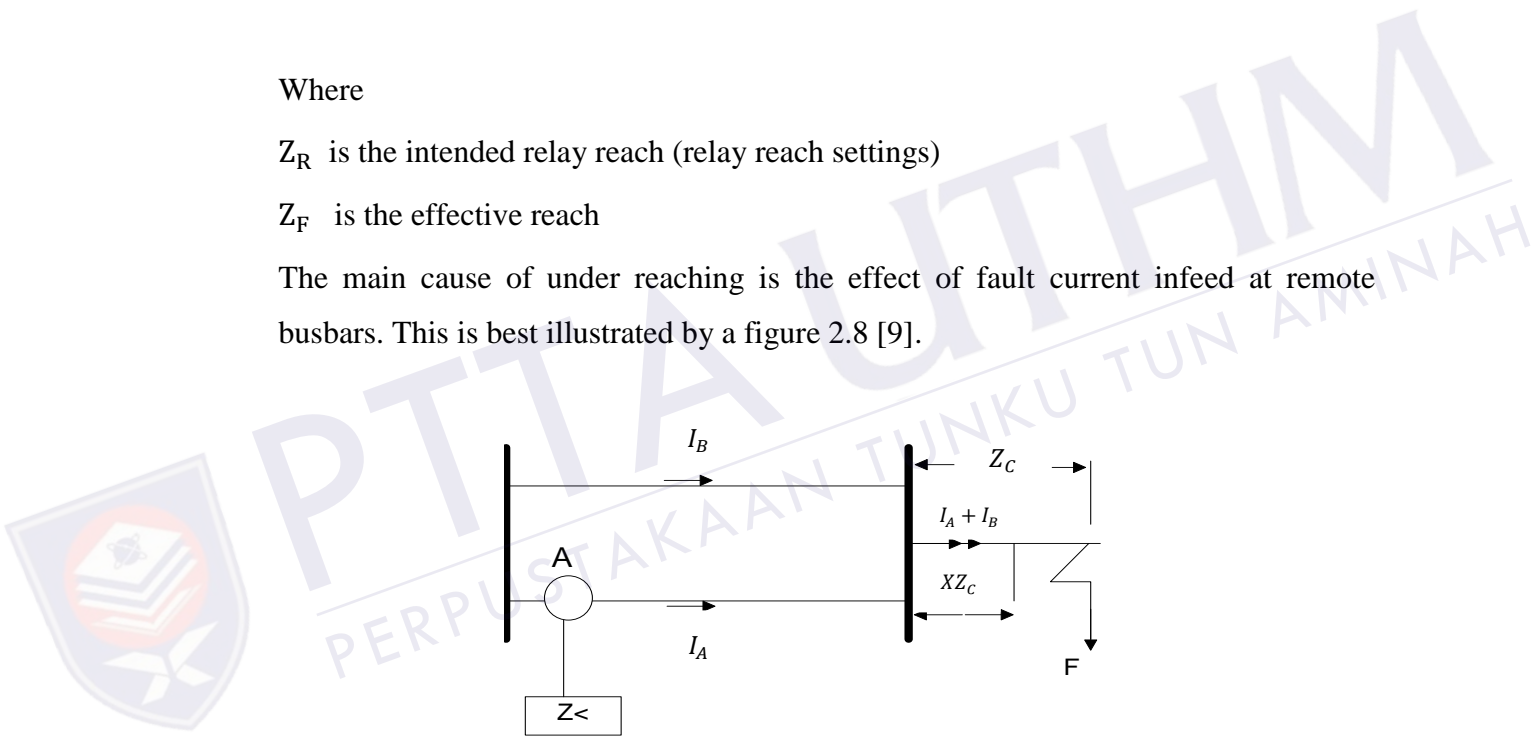


Figure 2.8: Effect on distance relays of infeed at the remote busbar [9]

the relay at A will not measure the correct impedance for a fault on line section Z_C due to current infeed I_B . Consider a relay setting of $Z_A + Z_C$. The effective reach is

$$Z_A + \left(\frac{I_A + I_B}{I_A} \right) * Z_C \quad (2.4)$$

The ratio between I_A and I_B can be included in the zones 2 and 3 calculations [8].

2.8.5 Earth Fault Recognition

The recognition of an earth fault is an important element in identifying the type of fault, the recognition is based on zero sequence current $3I_0 = I_n$, which have large values in earth fault [19].

$$I_a + I_b + I_c = I_n = 3I_0 \quad (2.5)$$

In MATLAB Simulink, the block SUM used to sum the vectors of currents and the fundamental magnitude deduced by Fourier Block.

2.8.6 Impedance Calculation of Phase-Phase Fault

To calculate the phase-phase loop, for instance during a two-phase short circuit $L_1 - L_2$ Figure 3.11, the loop equation is [19].

$$I_{L1} * Z_L - I_{L2} * Z_L = V_{L1-E} - V_{L2-E} \quad (2.6)$$

Where

V, I: The voltage and current in complex value

Z_L : The impedance value in phase to phase fault

$$Z_L = \frac{V_{L1-E} - V_{L2-E}}{I_{L1} - I_{L2}} \quad (2.7)$$

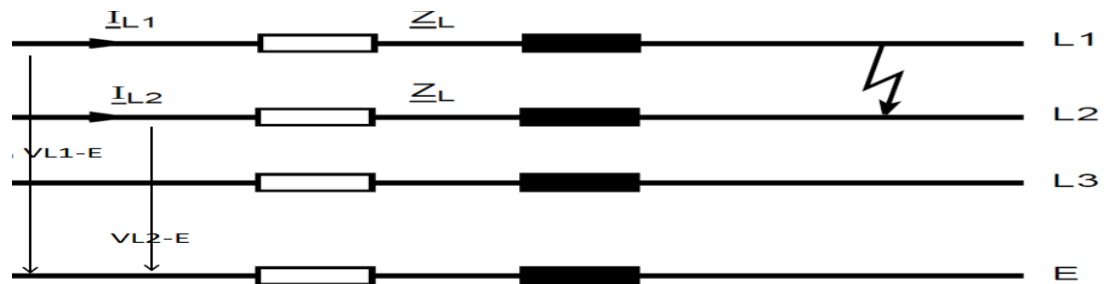


Figure 2.9: Two phase short circuit loop

2.9. Overcurrent Protection

Overcurrent protection is a protection against overload current which is beyond normally current rating of the equipment and against earth fault in case of short circuit to the earth. Relay time-current characteristics are divided into four classes such as definite time relays, very inverse time relays, extremely inverse time relays and inverse definite minimum time relays. In this project, Inverse Definite Minimum Time (IDMT) relay is used for the overcurrent protection. Figure 2.10 shows the characteristic of the four classes of (IEC 60255) comparing with time [11].

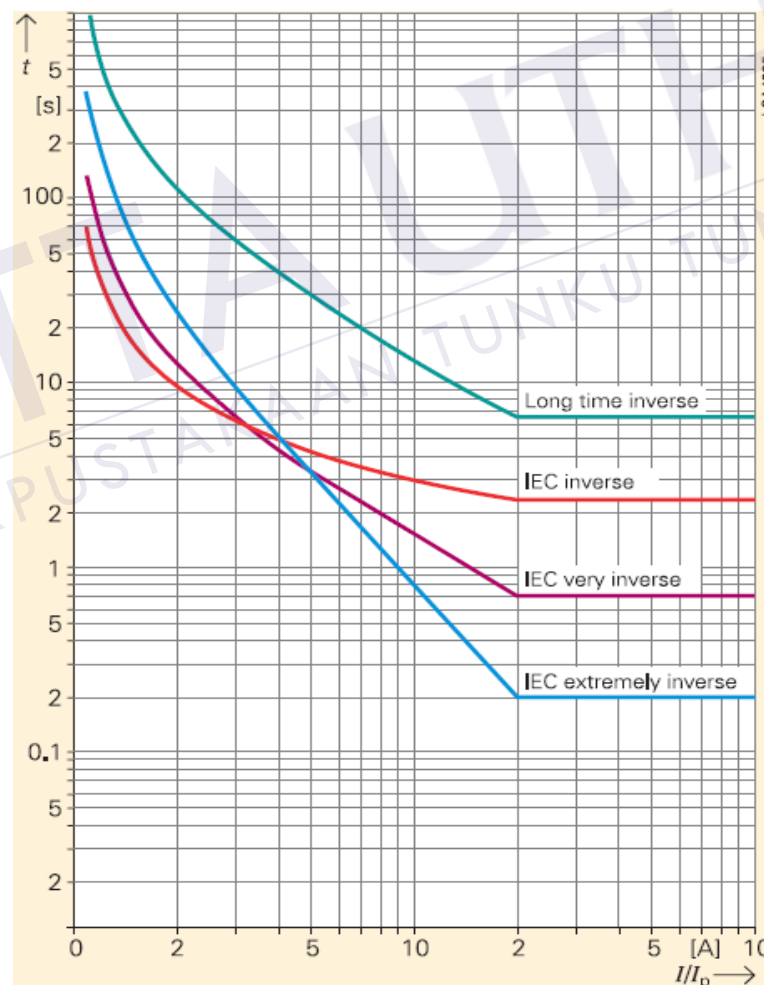


Figure 2.10: IEC 60255 Characteristic TMS=1

2.10 Directional Overcurrent Protection

When fault current can flow in both directions through the relay location, it's necessary to construct the response of the relay directional by the directional control facility. The facility is provided by use of additional voltage inputs to the relay. non-directional relays are applied to parallel feeders having a same source, any faults that occur on any one line will isolate both lines and completely disconnect the power supply. It is necessary to apply directional relays at the receiving end and to grade them with the non-directional relays at the sending end, to ensure correct discriminative operation of the relays during line faults. This is done by setting the directional relays R_1' and R_2' in Figure 2.11 with their directional elements looking into the protected line, and giving them lower time and current settings than relays R_1 and R_2 [9].

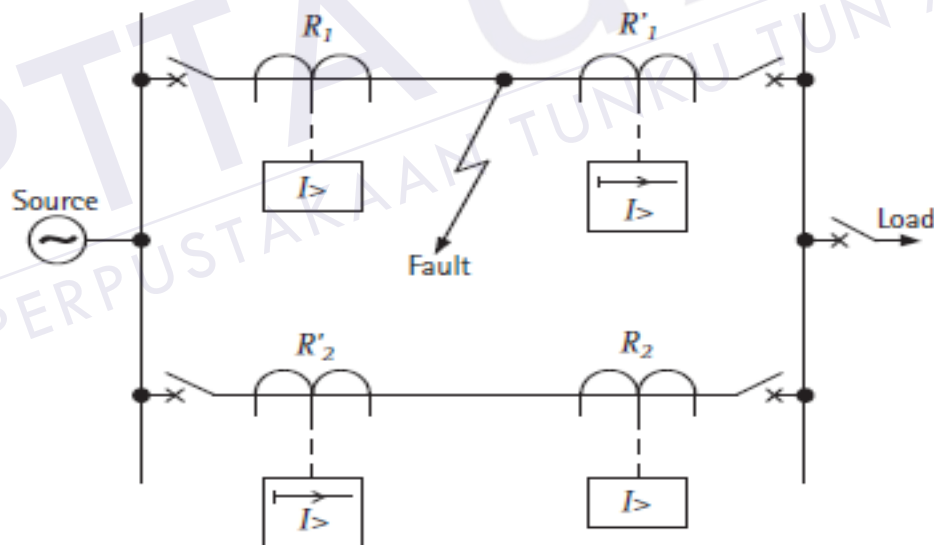


Figure 2.11: Directional relays applied to parallel feeders

CHAPTER 3

METHODOLOGY

3.1 Introduction

Several steps are taken in order to ensure that the desired objectives are achieved. This chapter will explain in detail on the methods taken to complete the project. This project is divided into four parts. The first part covers the modeling of the small grid (IEEE 9 busbars), which consists of three generators, nine bus bars, six transmission lines and three loads using ETAP to infer the load flow and short circuit analysis, the second part covers the calculations of the setting for both of the main protection (distance relays) and backup protection (overcurrent relays), which will be necessarily based on the grid ratings, the third part covers the simulation of the distance protection relays using MATLAB and finally, the fourth part covers the simulation of the overcurrent protection relays using ETAP.

Flow chart of the project is shown in Figure 3.1. These steps were followed in order to evaluate this project.

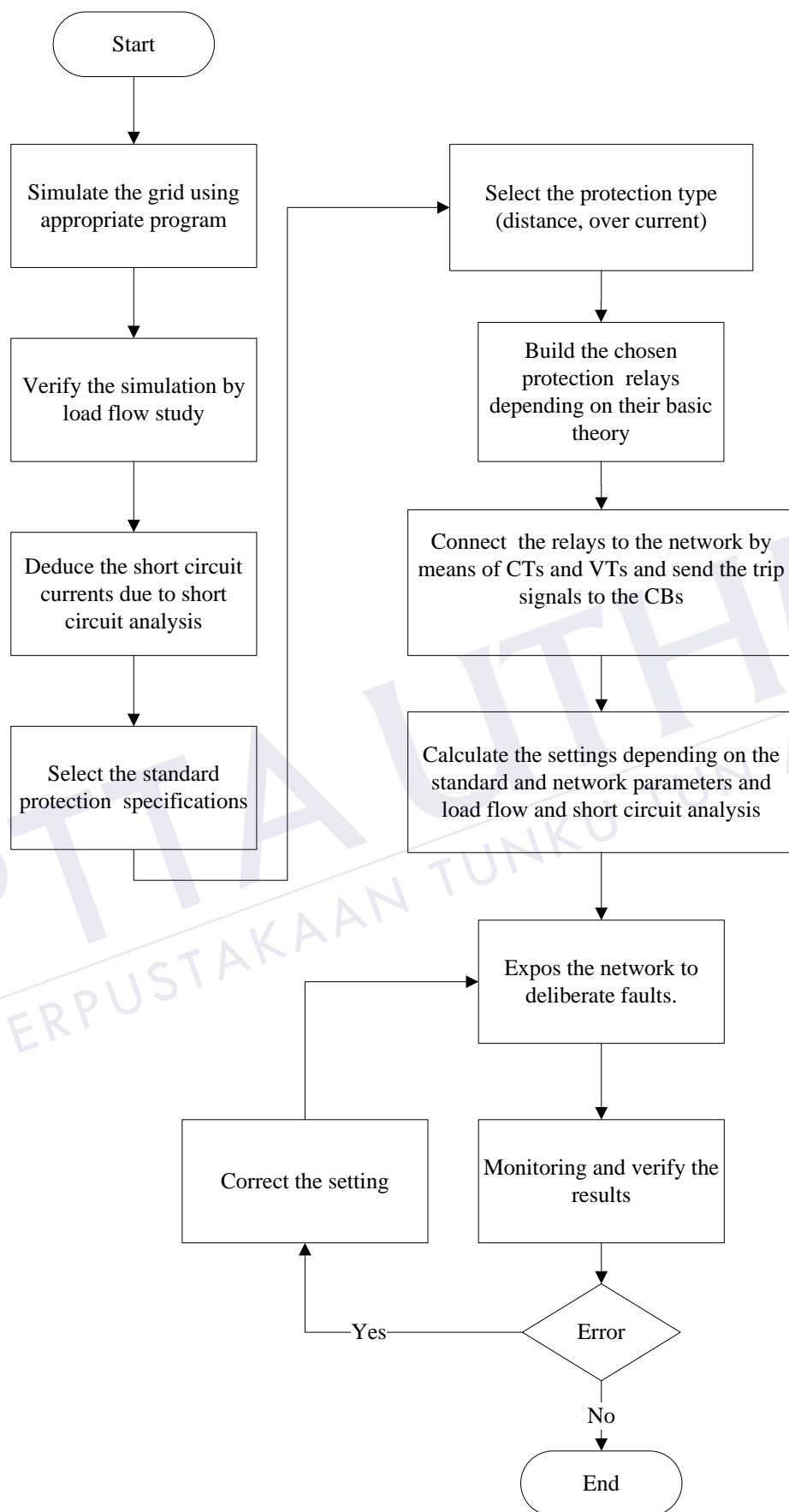


Figure 3.1: Flow Chart of the Project

3.2 Project Grid

The grid of the project is 230 kV IEEE WSCC, which consists of nine busbars, six transmission line, three loads and three generators. The network of the project is shown in Figure 3.2.

The interconnected system has been developed by using MATLAB Simulink and the ETAP software. By using these softwares, the values of the loaded currents (as well as P and Q Load flow) were determined to be in normal conditions and the faulty currents were at the particular buses.

The normal voltages of the network is 230 kV, load A is (125 MW, 50 MVAR), load B is (90 MW, 30 MVAR), load C is (100 MW, 35 MVAR), generator one is swing (16.5 kV/80 MVA), generator two is voltage control (18kV/80 MVA), generator three is voltage control (13.8 kV /110 MVA) and the impedance in PU is listed in Table 3.1 [12].

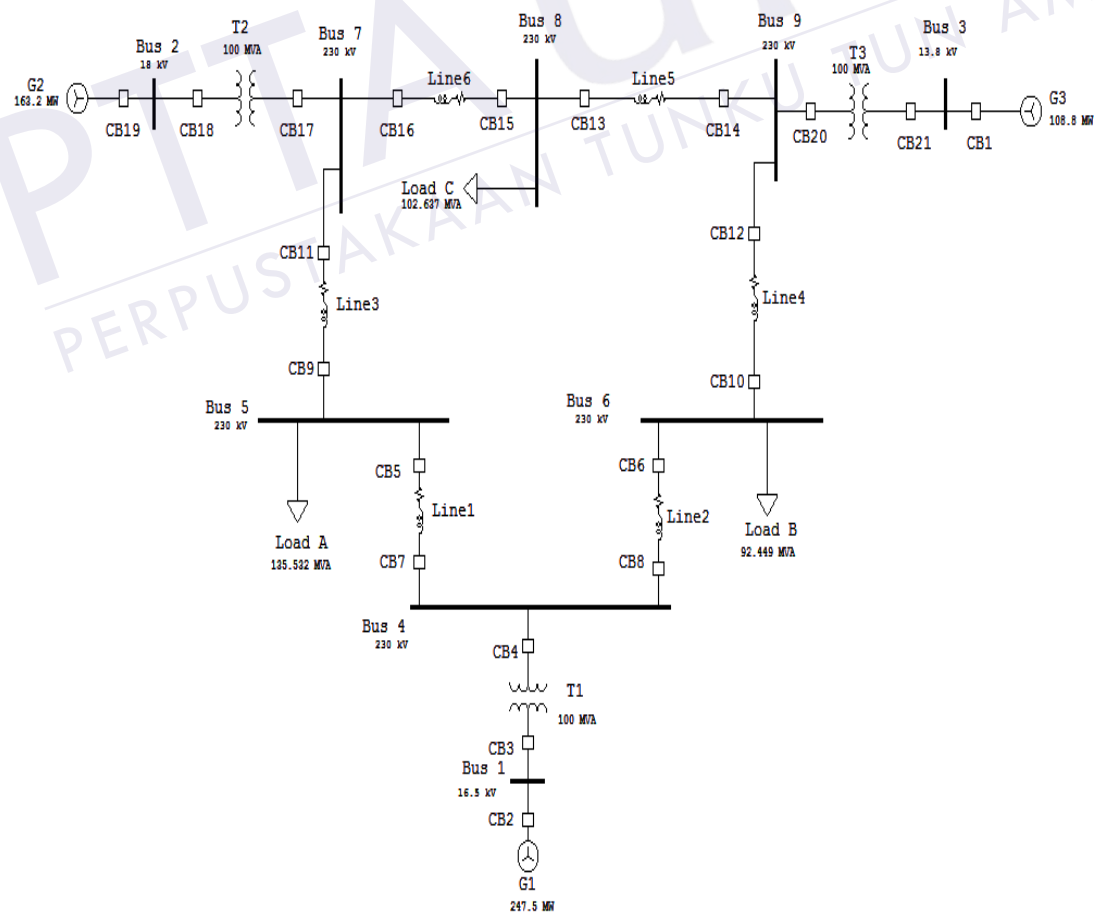


Figure 3.2: Grid of the project

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