A STUDY ON CASCADE PROTECTION IN TRANSMISSION LINES TO ANALYSE ZONE 3 DISTANCE RELAY USING PSCAD SOFTWARE

By

YAP CHUAN CHEW

FINAL REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

A STUDY ON CASCADE PROTECTION IN TRANSMISSION LINES TO ANALYSE ZONE 3 DISTANCE RELAY USING PSCAD SOFTWARE

by

Yap Chuan Chew

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

Ir. N. Perumal
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2007

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.

YAP CHUAN CHEW

ABSTRACT

The Final Year Project course is designed for student to do research; design and development work in each discipline, to produce practical solution. It provides opportunity for student to use the tools and techniques of problem-solving by engagement of the project. The objective of this project is to study the importance protection in Power Systems and also understand Wide-Area Protection. Transmission line faults in power systems are of major concern to electrical engineers working in power transmission and distribution. Despite the effort to prevent these faults within the system, they occur frequently and without any warning. Beside this, this project is used PSCAD (Power System Computer Aided Design) software as the tool to control the integrated operation of the protective system. This study will be able to give better understanding of the importance and need for the wide-area protection in the industry. PSCAD is used to simulate the transmission line that had been designed. On the other hand, different type of fault can be applied in the transmission line. From the simulation, it shows the duration period and also the starting period when the fault is occurred. In the discussion section, all finding would be discussed in more detail.

ACKNOWLEDGEMENTS

I would like to extend my heart-felt gratitude to everybody who has helped me make my final year project successful. Special thanks, to God almighty for the guidance, strength and for being with me every step of the way.

Beside that, I would like to take this golden opportunity to express my deepest gratitude to Mr. Ir. N. Perumal, who has been acting as my direct project supervisor, providing advice, motivation and assessments that led to the completion and execution of the project in terms of professional basis.

I takes this opportunity to honorably express my profound appreciation to Universiti Teknologi PETRONAS generally and the Electrical & Electronic Department specially, for providing a healthy working environment that resulted in a very fruitful project output.

Warm thankfulness credit to Assoc. Prof. Dr. Ravindra Nath Murkerjee and also Mr. Nursyarizal Mohd Nor as my assistant project supervisor, who contributed physically and mentally towards the best benefit of the project.

Not forget to thanks my loveable beloved family, colleagues and friends who have stood by my side during the entire past period. Special regards to my father Yap Soon Lim who has always provided the best gelidness and advice to by success.

Last but not least, to my beloved mother who always kept me close to her heart, and remember me continually in her prayers.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background of Study

In view of the increasing probability for outages due to the system overload, which are caused by the ever-increasing demand for electric power, utilizes are examining what modern information technology can contribute to improve this situation [1]. A challenging problem for the utility industry is system wide disturbances in power system due to the large scale distribution and the complexity of the power system. When a major power system disturbance occurs, protection and control actions are required to stop the power system degradation, restore the system to the normal state, and minimize the impact of the disturbance. The present control actions are not necessarily designed for fast-developed disturbance and thus may prove ineffective. Nowadays, more 'intelligent' equipments like sophisticated computer, communication and measurement technologies can be used at the local level to improve the overall emergency response.

The advances protection is a concept of using system-wide information together with distributed local intelligence and communicating selected information between separate locations to counteract propagation of the major disturbance in the power system. A great potential exists for advanced wide area protection and control systems, based on powerful, flexible and reliable system protection terminals, high speed communication, and skilled engineering by power system analysts and protection engineers in co-operation.

In the case of a fault, fault detection, clearance and system restoration should cause minimum system disturbance. High-speed protection relays and breakers are necessary, speed and proper executions of corrective actions are critical in preventing the system from entering the extreme state [1]. If the system cannot maintain voltage within desirable limits, the system will enter the extreme state. Load shedding or system islanding occurs in the extreme state to balance generation and load. Beside that, in the extreme state, it will also restore load-generation balance across the system; under voltage load-shedding schemes operate to avoid system voltage collapse. After load and/or generation shedding, the system enters a system recovery state. In this state, manual or automated reinsertion of generation and load occurs.

1.2 Problem Statement

The project can be used to study and analyze the cascading failure that normally happens at power transmission system. This study will involve the study of power systems protection and also study the Zone 3 distance relays. This reviews the present protection strategy to counteract large area disturbance addresses the potential that are derived from the advances in system operational, protection and control techniques.

1.3 Project Objectives and Scope of Study

The objectives of the project are:

- To understand the importance of protection in Power System and understand cascading protection.
- To study how Zone 3 works in the transmission lines
- To understand the characteristic of the distance relay that is used in Zone 3.
- To do simulation of the protective relays using PSCAD software by creating faults.

1.4 Feasibility of the Project within the Scope and Time Frame

To complete this project, we need to have full understanding of how Power System works and the method of protection that are used to prevent further damage in the system. With sufficient knowledge on Power System and wide-area protection, I can proceed to learn the Power System Computer Aided Design (PSCAD) software and design some fault analysis link using PSCAD software to do some analysis. All of this requires extensive research but nevertheless it can be completed on time within a considerable budget.

CHAPTER 2
LITERATURE REVIEW

2.1 Power System Protection

The main purpose of power system protection is to ensure safe operation of power system, care the safety of people, personnel and equipment. In addition, the task is to minimize the impact of un-avoidable faults in the system. From an electrical point of view, dangerous situations can occur from:

- overcurrents and
- overvoltages.

For example, an asynchronous coupling of networks results in high currents. Earth faults can cause high touch voltage and therefore endanger people. The most common problem that normally occurred is always voltage and/or current out of limit. Thus, the aim is to avoid overcurrent and overvoltages to guarantee secure operation of power systems [2].

For the safety of the components, the oil temperature, gas pressure in gas insulated components etc is also necessary to regard device-specific concerns. Although this point is not directly related to electrical values, but, as mentioned, they always come from or lead to unwanted high voltages or currents.

Another issue is mechanical stress. Whenever power is converted electromechanically, one has to consider not only the electrical but also the mechanical equipment. An example is mechanical resonance of steam turbines due to underfrequency.

Nowadays, electromechanical protection devices are replaced by microprocessor based relays with a number of integrated features. Currents and voltages are suitably transformed and isolated from the line quantities by instrument transformers and converted into digital form [2]. These values are inputs for several algorithms, which then reach tripping decisions.

For the design and coordination of protective relays in a network, some overall rules have become widely accepted:

Selectivity: It mean that a protection system should disconnect only the faulted part or the smallest possible part containing the fault of the system in order to minimize fault consequences.

Redundancy: A protection system has to care for redundant function of relays in order to improve reliability. Redundant functionalities are planed and referred to as back-up protection. Moreover, redundancy is reached by combining different protection principles, for example distance and differential protection for transmission lines.

Grading: For the purpose of clear selectivity and redundancy, relay characteristics are graded. This measure helps to archive high redundancy whereas selectivity is not disabled.

Security: The security of a relay protection system is the ability to reject all power system events and transients that are not fault so that healthy parts of the power system are not unnecessarily disconnected [2].

Dependability: The dependability of a relay protection system is the ability to detect and disconnect all faults within the protected zone.

2.2 Different Type of Power System Protection

In common usage, relays may mean only the protection system. In the real situation, the actual protection system consists of many other subsystems, which contribute to the detection and removal of fault. Figure 1 shows the basic element of the protective chain. Protection system usually comprises five components:

- Batteries
- Relays
- Transducers
- Circuit breakers
- Bus configurations

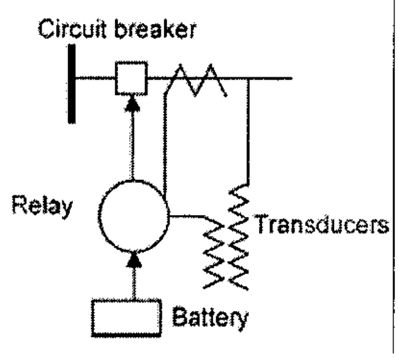


Figure 1: Element of a Protection System

2.2.1 Batteries

Batteries are used to provide power in case of power disconnection in the system. In science and technology, a battery is a device that stores chemical energy and makes it available in an electrical form. Batteries consist of electrochemical devices such as two or more galvanic cells, electrolytic cells, fuel cells, or flow cells.

2.2.2 Relays

To sense the fault and initiate a trip, or disconnection, order. A relay is an electrical switch that opens and closes under the control of another electrical circuit.

In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched off, the armature is returned by a force approximately half as strong as the magnetic force to its relaxed position. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing (electrical breakdown).

2.2.3 Transducers

A transducer is a device, usually electrical, electronic, or electro-mechanical, that converts one type of energy to another for various purposes including measurement or information transfer. In a broader sense, a transducer is sometimes defined as any device that converts a signal from one form to another.

2.2.4 Circuit Breakers

Circuit breaker is to open or close the system based on relay and autorecloser commands. A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

2.3 Experiences with Large Area Disturbances

Extensive literature is available on disturbances that have occurred throughout the world. While the initial, which have triggered the disturbances, varied the results were one or more of the following:

- Frequency instability
- Voltage instability

- Cascade tripping due to overloading

2.3.1 Frequency Instability

The tripping of generators or heavily loaded transmission lines usually arises by the frequency instability. Transient or angular instability is very often a precursor to frequency decline in a power system.

2.3.2 Voltage Instability

When heavy system loading creates large reactive power demands will occur voltage instability that result in an excessive voltage gradient between generation sources and load centre.

2.3.3 Cascade Tripping

When there wan a tripping of a transmission circuit, cascade tripping typically commences, due to the operation of a protective relay, causes overloading of the remaining circuits.

Cascade tripping of generators usually occurs during a voltage decline on the system when, in attempting to increase reactive power output, field current limiters operate to trip the unit leading to a rapid deteriorating voltage profile followed by similar tripping of remaining generators [1].

2.4 Cascading Failure

A cascading failure is failure in a system of interconnected parts, where the service provided depends on the operation of a preceding part, and the failure of a preceding part can trigger the failure of successive parts. Redundant parts can lessen the impact of, but not prevent, a failure.

2.4.1 Cascading Failure in Power Transmission

Cascading failure is common in power grids when one of the elements fails (completely or partially) and shifts its load to nearby elements in the system. Those nearby elements are then pushed beyond their capacity so they become compromised and shift their load onto other elements. Cascading failure is a common effect seen in high voltage systems, where a single point of failure on a fully loaded or slightly overloaded system results in a sudden spike across all nodes of the system. This surge current can induce the already overloaded nodes into failure, setting off more overloads and thereby taking down the entire system in a very short time.

This failure process cascades through the elements of the system like a ripple on a pond and continues until substantially all of the elements in the system are compromised and/or the system becomes functionally disconnected from the source of its load. For example, under certain conditions a large power grid can collapse after the failure of a single transformer.

Monitoring the operation of a system, in real-time and judicious disconnection of parts can help stop a cascade. Another common technique is to calculate a safety margin for the system by computer simulation of possible failures, to establish safe operating levels.

2.4.2 2003 Italy Blackout

"Power went off at about 03:20am local time on 28 September 2003. Initial reports from Italy's electricity supplier, ENEL (Ente Nazionale per l'energia ELettrica), stated that the power line which supplied electricity to Italy from Switzerland was damaged by storms, causing it to trip and also the two 400kV power lines between France and Italy to trip due to sudden increased demand from those two power lines. The cascading effect disrupted power supply to Italy from France and Switzerland. ENEL lost control of the grid in the next 4 seconds, with the lines tripped one by one amid the cascading effect. Swiss electricity company ATEL

(Aare-Tessin Ltd.) later concurred that a power line between Switzerland and Italy went out for a few hours. It was also the most serious blackout in Italy in 20 years".

2.5 Third Zone (Zone 3)

Zone 3 of a step-distance protection scheme has been identified as one of the contributing causes of cascading failures in power system. After reexamine the application of zone 3, it is one of the most commonly used back-up protection systems on HV and EHV transmission lines step distance protection scheme. Zone 3 is an over-reaching zone of protection which is considered the protection of last resort when certain elements of the protection chain [3]. Zone 3 protection can be removed by using pilot relays, or computer relays or both or a transfer trip capability. But this solution for all zone 3 relays may be prohibited expensive and unnecessary. If used, the zone 3 setting must also need to consider other stressed system condition such as voltage instability, generator loss or field, or system instability any one of which can influence on the relay characteristic.

Recent blackouts have led to a discussion of the role played by the third zone of step-distance protection schemes which are universally used to protect transmission and distribution lines. It is recognized that a power system and its protection equipment is designed in such a way that the system can ride through a sequence of credible contingencies without causing wide-spread outages. However, it has been observed that unwanted third zone operations caused by unexpected loading conditions have often contributed to the cascading outage eventually leading to major blackouts affecting millions of people [3].

After the study, this Zone 2 is still considered to be necessary; the influence of various types of system configurations on protection requirements, and summarizes the failures in the chain of protective equipment which the third zone is designed to back up.

Basically, zone 3 is using the distance relay which provided the backup protection in case of the failure of the primary protection. Zone 3 is used in combination with the derivatives of the voltage and current to prevent the unwanted fault (maloperation).

2.5.1 Third Zone Principle

Step distance protection can be called non-pilot application of distance relaying. The Zone 1 is set to trip with no intentional time relay. Zone 1 is set for approximately 80-90% of the transmission line impedance so as to avoid unnecessary operation for fault beyond the remote terminal. For Zone 2, is to protect the remainder of the line with an enough margin. Zone 2 relays have to be time delayed to coordinate with relays at the remote bus. Typical Zone 2 time delays are of the order of 15-30 cycles.

Zone 3 was applied as a remote backup for Zone 1 and Zone 2 of an adjacent line in the event that a relay or breaker failure prevented clearing the fault locally. Zone 3 operations must be delayed to coordinate with the several Zone 2 relays that it overreaches [3]. 90 cycles is the common timer setting since there are no standards in this regards.

In addition, Zone 2 has a different rationale for its application and eliminating it is not an option. Zone 2 is applied to protect the end of the line which not protected by Zone 1 when the failure of the pilot relay and must overreach the end of the line. The reach can be reduced and time coordination can be employed without giving up the overreaching function if the reach setting encroaches on any of the stressed system or loadability concerns.

2.6 Improving Loadability of the Third Zone

Loadability problems of over-reaching zones of protection have been recognized since the early days of protection. Where third zone as a remote back-up zone is deemed to be necessary, certain technical innovations are available to alter its loadability limit. These innovations are more readily implemented in modern computer relays. However, even the electromechanical relays do have limited ability to improve their loadability. One thing to note is that load excursions are balanced phenomena, so that the presence of unbalanced currents (negative sequence) would indicate a fault, and thus loadability should not be an issue when negative sequence currents are present [3]. Third zone characteristic for three phase faults is the only one where load conditions could be confused with remote faults. It is also unlikely that three phase faults would have a significant fault resistance, so that the third zone shape for such faults could be considerably modified to reduce the resistive reach of the relay, thus increasing the loadability of the relay. These and other improvements are generally available only in computer relays.

2.7 Distance Relay

Distance functions have been in use for many years and have progressed from the original electromechanical types through analog types and now up to digital types of functions. Distance relay is one of the most popular types of protection employed for protective transmission lines. It can be set to operate for specific zones. The distance relay offers fast operating times (1 cycle). Besides that, it can work independently or in co-ordination with other relays in the system. Easy to design and proven to be the best solution for wide range of system configuration.

2.7.1 Distance Relay Mho Function

A simple mho distance function, with a reach of Z ohms, is shown in Figure 2. This diagram is exactly equal to an R-X diagram except that all of the impedance vectors have been operated on by the current I. The mho function uses the current and voltage measured at the relay to determine if the apparent impedance plots within the mho characteristic. The determination is made by comparing the angle between the operating quantity (IZ - V) and the polarizing quantity (V, where V = IZf). If the angle is less than or equal to 90¡, then the fault impedance Zf plots within the characteristic, and the function will produce an output. If the angle is greater than 90¡, then Zf falls outside of the characteristic and no output will be produced [2]. Assume that the angle of maximum reach (q) and the angle of ZL (f) are equal.

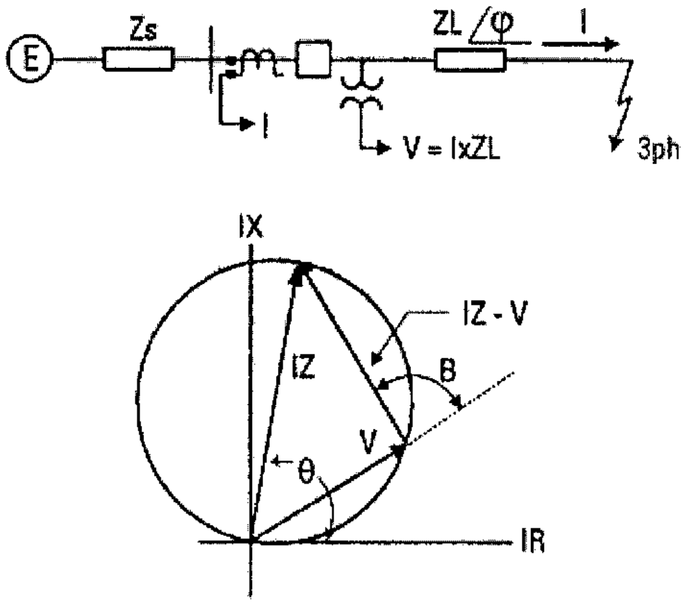
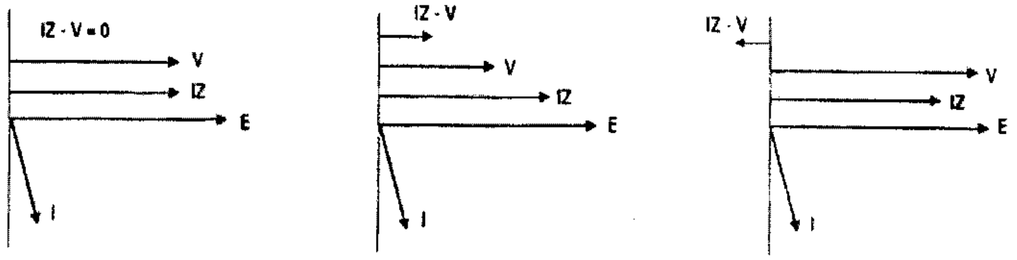


Figure2: Simple Mho Function

On that basis, the conditions shown in Figure 3 will be obtained. The key point to note in this phasor analysis (a convenient way to view relay performance) is the magnitude of the IZ - V (Vop) phasor and its relationship to the V (Vpol) phasor. Operation will occur whenever Vop and Vpol phasors are within 90¡ of each other and provided both Vop and Vpol are greater than the minimum values established by the sensitivity of the relay design. For the balance point fault, IZ-V is zero; therefore no operation occurs, which is expected. For an internal fault, IZ -V and V are in phase; therefore the function operates as expected. For the external fault, operation does not occur because IZ V and V are 180¡ out of phase [4]. Observe that for the balance point fault, the V is exactly equal to IZ. This is true for the three-phase fault shown (also for a phase-to-phase fault) and for a phase distances function only. For a ground distance function, this will only be true if the function includes zero sequence current compensation as discussed later in this paper.



a. Balance Point Fault, V = IZ b. Internal Fault, V < IZ c. External Fault, V > IZ

Figure 3: Phasor Analysis of Operation of Simple Mho Function

The polarizing quantity for this simple mho distance function is simply equal to the fault voltage V, therefore the function is said to be self-polarized and has the simple characteristic shown in Figure 2.

2.8 Distance Relay Basics

Both first and second zone relays are forward looking relays. The first zone is typically set between 80% and 90% of the line impedance. The second zone is typically set between 125% and 150% of the line impedance. The second zone of protection looks through the next bus in the forward direction, but care must be taken to make sure that it does not over reach. The third zone of protection can be set to look either forward of backwards. If it is set in the forward direction, then the second zone may be set to less than 125% and the third zone may be set up to 150% of the line. If it is set in the reverse direction, it usually is set up to 150% of the line impedance. The protection engineer must make sure the third zone relay only looks backwards through one bus. This task becomes particularly tedious when more than two lines are connected to a bus. Figure 4 below shows the typical protection zones with a third zone reverse relay.

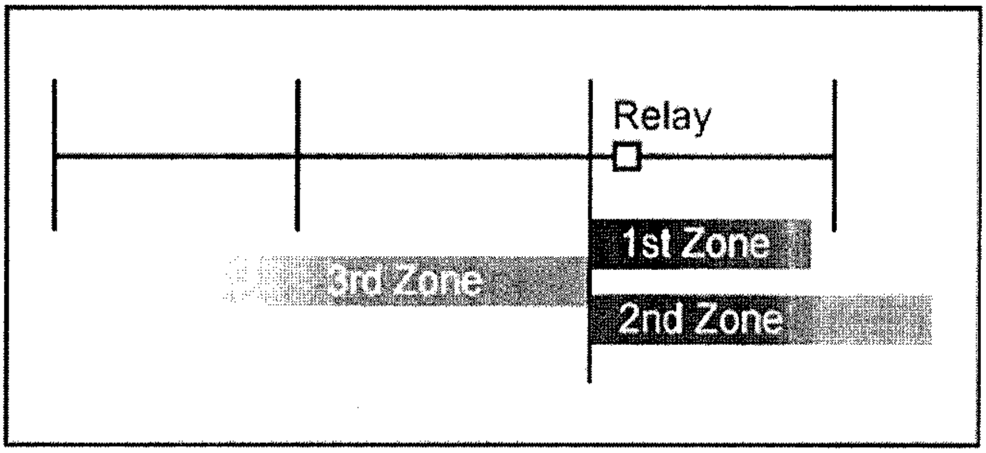


Figure 4: Typical distance protection scheme utilizing a third zone reverse relay.

Distance relays have several elements. The first of these elements is a directional element. This makes sure that the relay will not trip unless the fault is in the direction (forward or reverse) the relay is set for even if the impedance enters the relay's characteristic. Another element is the timing element. Since the first zone is the shortest zone and only looks at the line it is connected to, it's time delay is minimal (usually .1s or less). Since the second zone is still forward looking, but looks farther than the first zone, it's time delay is longer. The third zone time delay is the longest (up to three times as long as the second zone) since third zone reverse protection is primarily back-up for the first and second zones of the other lines connected to the bus. Ideally, the first and second zone of the relay would trip and the third zone would never be used.

Another element is an impedance element. This element measures the impedance of the line by using the equation

$$\frac{Vsel}{Isel}$$

where V and I are phasor quantities of the selected (faulted) voltage/current pair. If the impedance falls within the relay characteristic and the timing and directional criteria are met, the relay will trip.

2.9 The Advantages/Disadvantages of Distance Protection

- Comparing the local current with the local voltage is an effective alternative to comparing it with remote current.
- In a distance relay, the discrimination between an internal and an external fault is not as definite as in a differential relay. The voltage changes gradually with the location of the fault; consequently there is no appreciable difference between the local voltage and current signals due to faults on either side of the remote current transformer (CT).
- In a differential relay, the current in the remote end CT reverses for a fault beyond the CT. this abrupt discontinuity makes the in-zone / out-of-zone selectivity easy.
- Distance relay have two major advantages which often outweigh the in-zone / out-of-zone selectivity issue: - they do not require a communication channel and they can provide back-up protection to the relays protecting the next zone of the system.
- A distance relay is designed to trip for all fault located between the relay and the specified reach point (the impedance setting Z_R).this ensures discrimination between faults in different line sections.

2.10 Zones of Protection

The various zones of measurement enable correct coordination between distance relays on a power system must selected carefully of the reach settings and tripping times. Basic distance protection will comprise instantaneous directional Zone 1 protection and one or more time delayed zones. Typical reach and time settings for a 3-zone distance protection are shown in Figure 5. The relay manufacturer's instructions should be referred to determine the settings for a particular relay design or for a particular distance teleprotection scheme, involving end-to-end signalling.

2.10.1 Zone 1 Setting

A setting of up to 80% of the protected line impedance for instantaneous Zone 1 protection usually has from electromechanical/static relays. Settings of up to 85% may be safe for digital/numerical distance relays. The resulting 15-20% safety margin ensures that there is no risk of the Zone 1 protection over-reaching the protected line due to errors in the current and voltage transformers, inaccuracies in line impedance data provided for setting purposes and errors of relay setting and measurement. Otherwise, there would be a loss of discrimination with fast operating protection on the following line section. Zone 2 of the distance protection must cover the remaining 15-20% of the line.

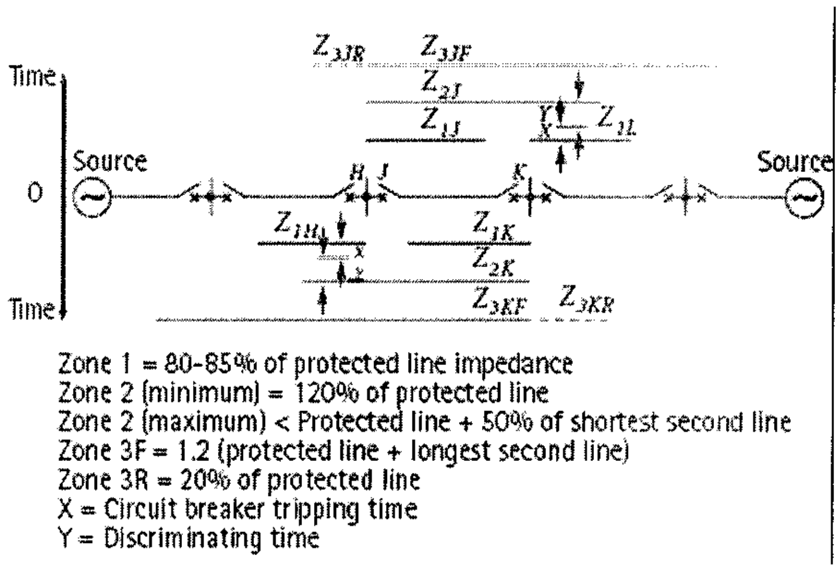


Figure 5: Typical time / distance characteristics for Zone 3 distance protection.

2.10.2 Zone 2 Setting

The reach setting of the Zone 2 protection should be at least 120% of the protected line impedance. It is common practice to set the Zone 2 reach to be equal to the protected line section +50% of the shortest adjacent line in many applications. This is to ensure that the resulting maximum effective Zone 2 reach does not extend beyond the minimum effective Zone 1 reach of the adjacent line protection. In electromechanical and static relays, Zone 2 protection is provided either by extending the reach of the Zone 1 elements or by separate elements after a time delay that is initiated by a fault detector. In most digital and numerical relays, the Zone 2 elements are implemented in software.

To ensure grading with the primary relaying applied Zone 2 tripping must be time-delayed to adjacent circuits that fall within the Zone 2 reach. Therefore complete coverage of a line section is obtained, with fast clearance of faults in the first 80-85% of the line and rather slower clearance of faults in the remaining section of the line.

2.10.3 Zone 3 Setting

Zone 3 is a remote back-up protection for all faults on adjacent lines that is time delayed to discriminate with Zone 2 protection plus circuit breaker trip time for the adjacent line. Zone 3 reach should be set to at least 1.2 times the impedance presented to the relay for a fault at the remote end of the second line section.

On organized power systems, the effect of fault current in feed at the remote bus bars will cause the impedance presented to the relay to be much greater than the actual impedance to the fault and this needs to be taken into account when setting Zone 3. In some systems, variations in the remote bus bar in feed can prevent the application of remote back-up Zone 3 protection but on radial distribution systems with single end in feed, no difficulties should arise.

2.11 Conventional Time Stepped Distance

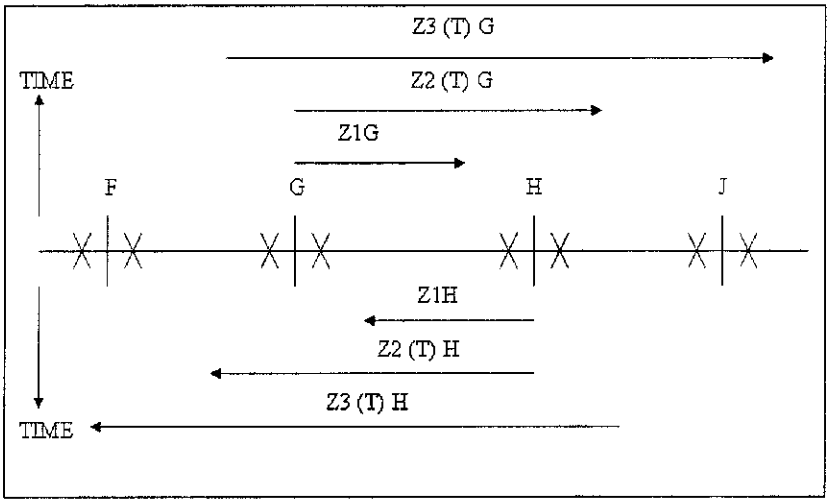


Figure 6: Conventional Distance Scheme

- ✓ Zone 1 reach required to cover 80% of the protected line.
- ✓ Zone 2 reach required to cover the 20% end zone and provide time delayed back-up protection for faults on the remote line end bus bars.
- ✓ Zone 2 reach normally set to cover the largest of protected line +50% of next shortest line or 120% of protected line.
- ✓ Zone 3 provides back-up protection for unclear faults in adjacent line sections. Zone 3 usually set to 1.2x impedance presented to relay for a fault at the remote end of longest adjacent line.
- ✓ Zone 2 time delay set to discriminate with primary protection of next line section including current breaker trip time. Usually 0.2-0.3s is satisfactory.
- ✓ Zone 3 time delay required to ensure the Zone 3 element discriminates with protection at G, H and J.

2.12 Distance Protection

Distance relaying is considered a transmission line protection method, where the time delay cannot be promoted and selectivity cannot be obtained by overcurrent relaying. Distance protection is used for secondary and main lines. Distance relaying measures the ratio V/I at the relay location, which give the measure of distance between the relay and the fault location. The impedance (resistance/ reactance/ admittance) of a fault loop is proportional to the distance the relay location and the fault point. For a given setting, the distance relay picks up when the impedance measured by is less than then set value. Since it protects a certain length of line, thus it is called distance relay.

2.13 Hidden Failures in Protection Systems

The role of hidden failures in protection systems in creating cascading outages and catastrophic failures has received considerable attention in relaying literature [7]. Given that a certain number of hidden failures in protection systems are unavoidable it becomes necessary to determine which hidden failures are potentially most damaging to the power system. This requires the determination of "regions of vulnerability" and "severity index" of each possible hidden failure [8].

One may consider that tripping under load of a zone 3 is really a "hidden failure". The technique described in [7], [8] can be applied to determine the zone 3 elements which are critical in the sense of their potential to create cascading failures if they tripped on unusual load excursions. It is at these critical locations that immediate corrective action must be taken. This may include elimination of zone 3 functions and providing alternative back-up protection systems, or possible replacement with computer relays with advanced load discriminating capability.

2.14 Different Type of Distance Relay in Market

1. LFZP

Optimho is an extremely reliable and dependable distance relay, time-served over many relay-years in installations worldwide. It offers excellent protection, without requiring a multitude of settings.

The range of applications includes:

- Main and back-up protection of overhead lines includes transformer feeders.
- Protection of solid or resistance earthed systems.
- Three-pole or single-and-three-pole tripping, with or without the aid of a signaling channel.
- On-site replacement of obsolescent electro-mechanical or switched static distance relays.

Customer Benefits

- Mho distance protection in a simple device
- Remote interrogation reduces need for site visits
- Accurate fault information provides for in-depth fault analysis
- Self-diagnosis reduces maintenance costs.

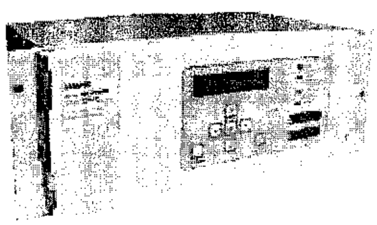


Figure 7: Optimho

2. MiCOM P43x

The distance protections devices of the MiCOM P43x range are designed for selective short-circuit protection, ground fault protection and overload protection. They can be applied in all kind of medium-, high- and extra-high-voltage systems.

The wide range of protection functions covers all kind of applications in cable and overhead line protection. In addition numerous back-up protection and control functions are available. P43x provide four setting groups for easy adaptation to varying system operation conditions.

The user-friendly user interface as well as the various communication interfaces allows easy and entire device settings and readings from extensive recordings. Numerous integrated communication protocols allow easy interfacing to almost any kind of substation control or SCADA system. Furthermore the integrated protection interface InterMiCOM provides direct end-end communication between two protection devices.

The especially flat compact case of P430C as well as the standard 19" modular cases of P433, P435 and P437 with variable number of plug-in modules provide a flexible solution for easy integration of the devices into the substation. Both case variants are available for flush mounting and wall mounting.

Customer Benefits

- 1A/5A settable via software
- Two communication interfaces (for substation control system and remote access)
- Protection interface InterMiCOM

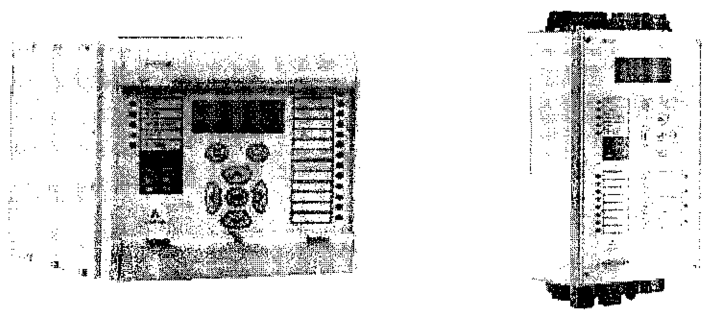


Figure 8: P430C

3. MiCOM P432 and P439

The MiCOM P432 and P439 are cost effective one-box solutions for integrated numerical distance protection and control.

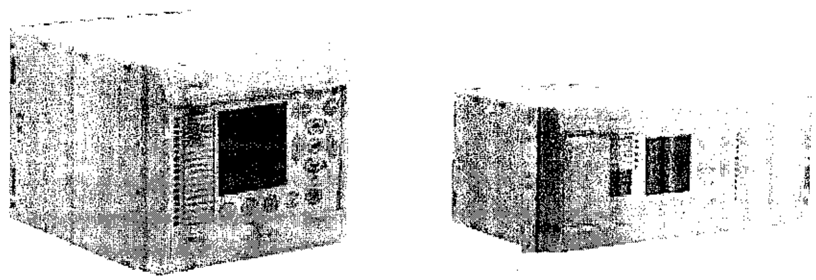
The broad spectrum of protection functions enables the user to cover a wide range of applications in the area of selective short-circuit protection, ground fault protection and overload protection. They can be applied in all kind of medium-, high- and extra-high-voltage systems. In addition, numerous control functions are available. Thanks to the provision of four setting groups, the devices are readily adapted to varying conditions in system operation.

The control functions are designed for the control of up to six (P439) or ten (P432) electrically operated switchgear units equipped with electrical check-back signaling located in the bay of medium- or high-voltage substations. For the selection of the bay type the devices are provided with over 250 predefined bay types and allow download of customized bay type.

Customer Benefits

- Protection and Control in one box
- Huge number of predefined bay types
- 1A/5A software setting

- Two communication interfaces (for SCADA and RTU)
- Numerous switchable communication protocols (for SCADA, interface)



(a) (b)

Figure 9: (a) P439 (b) P432

4. MiCOM P441, P442, P444

MiCOM P441, P442 & P444 numerical full scheme distance relays provide flexible, reliable, protection, control and monitoring of transmission lines.

The MiCOM distance protection relays can be applied for a wide range of overhead lines and underground cables in high and extra high voltage systems. Based on a patented, proven algorithm with more than 2 decades of established field experience, the P441, P442 & P444 relays provide an unparalled combination of speed, security and selectivity for any kind of power system fault. The wide range of communication options help in easily connecting the relay to any type of Digital Control System or SCADA.

The optional interMiCOM protection communication along with powerful graphical programmable scheme logic enables developing user-defined protection schemes and solutions.

Customer Benefits

- Dual Algorithms
- Polygonal characteristic (quadrilateral)

- Fastest operating time: 0.85 cycles
- Wide choice of channel aided scheme
- Power swing detection / Out of Step protection
- Inter relay protection communication
- Option of multiple communication protocols and interfaces, including IEC61850
- User customizable by graphical tools

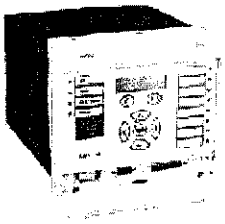


Figure 10: MiCOM P440

5. MiCOMho P443 and P445

Transmission and distribution systems are essential to route power from generation to consumers. The mode of transport is generally via overhead lines, which must have maximum inservice availability. The exposed nature of lines make them fault-prone, and protection devices must trip to initiate isolation of any faulted circuit.

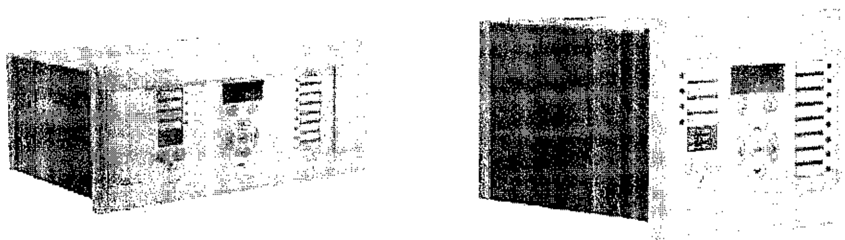
The MiCOMho provides fast, highly selective protection, to trip for genuine line faults. Advanced load blinding and disturbance detection techniques - such as power swing blocking - ensure stability when no tripping is required. Selectable mho and quadrilateral (polygon) characteristics allow versatile deployment as main protection for all effectively-grounded transmission and distribution circuits, whether lines, cables or hybrid. Series compensated line application is supported.

Multiple main protection elements reside inside each relay: Distance, delta directional comparison protection, and directional earth/ground fault unit protection

(DEF). This permits simplified application and spares holding, as the MiCOMho can be adopted as THE standard protection platform.

Customer Benefits

- P443: Sub-cycle fault clearance (0.7 to 1 cycle)
- Simple set mode - the relay determines its own settings from protected line data
- Power swing blocking without the need for settings
- Integral teleprotection via MODEM, fiber, or MUX channel.

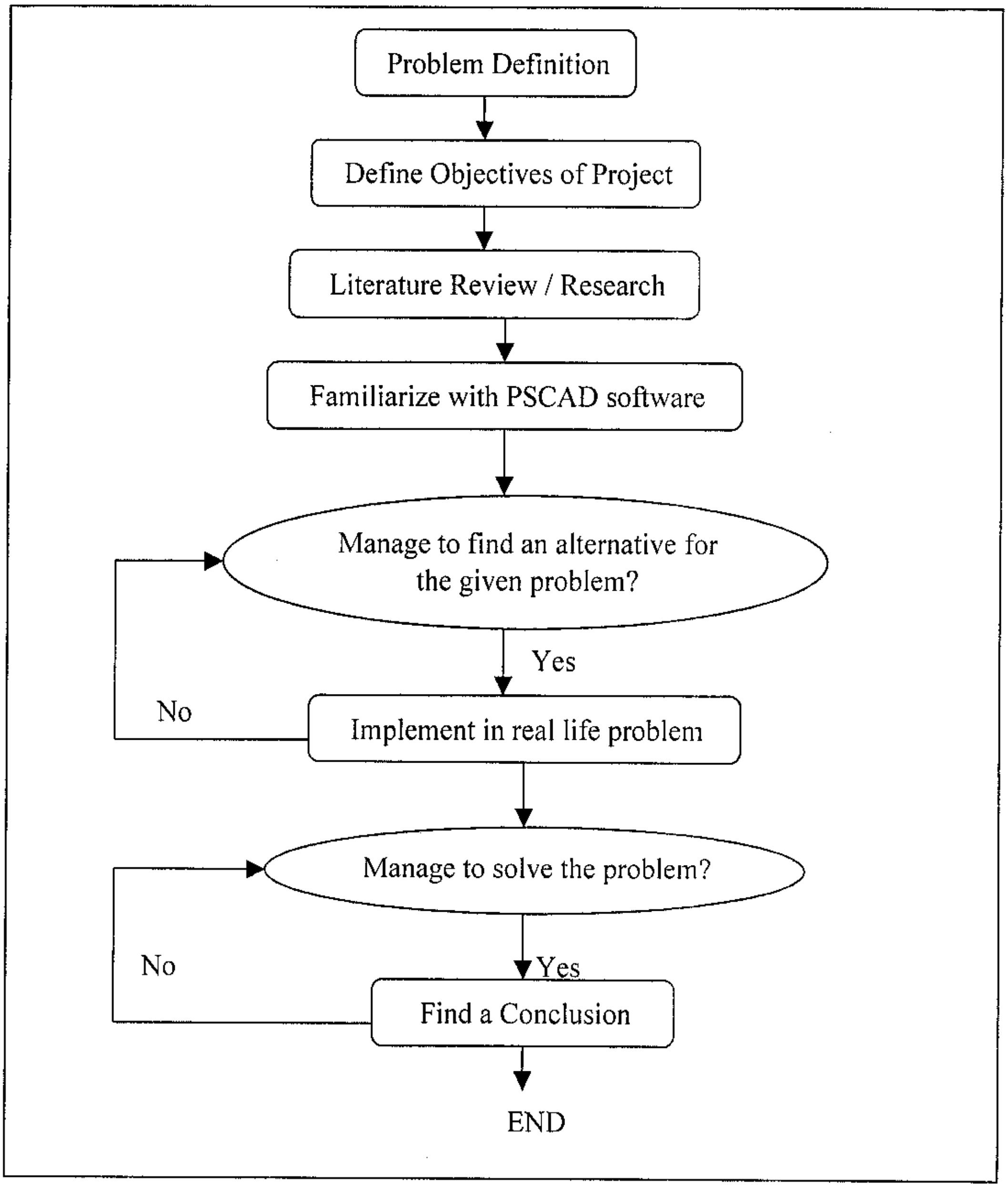


(a) (b)

Figure 11: (a) P443 (b) P445

CHAPTER 3
METHODOLOGY / PROJECT WORK

The study on cascade protection using zone 3 distance relays is to be developed after following a standard set of procedures and steps to be applied and implied within the whole process. The flowchat of the project approach in achieving the objectives of the project is as shown:



3.1 Tool

3.1.1 PSCAD / EMTDC

PSCAD stands for Power System Computer Aided Design. The application of electromagnetic transient simulation in electric power systems was made possible with the initial development of the EMTP (Electro-Magnetic Transient Program) by Dr. Hermann Dommel. Utility engineers who applied EMTP to resolving power system problems were rewarded with an exciting new method of analysis. Today, electromagnetic transient's simulation is utilized around the world and has become a essential method for studying electric power system. When users of EMTP attempted to apply early version of the program to High Voltage Direct Current (HVDC) transmission systems, considerable frustration was experienced. Using the same published algorithm as EMTP, entirely new code was written at Manitoba Hydro to accommodate electromagnetic transients of HVDC converters and controls.

PSCAD is a family of tools designed to help simulate power systems. EMTDC (Electro-Magnetic Transient of high voltage Direct Current converters and controls) and PSCAD are a group of related software packages that provide the user with very flexible power systems electromagnetic transient simulation tools. EMTDC is software that actually performs the electromagnetic transient analysis on the user defined power system. The various software modules that comprise PSCAD are the graphical user interface to EMTDC. Together, these two software packages are referred to as PSCAD/EMTDC.

CHAPTER 4
RESULTS AND DISCUSSION

For the part 2 of Final Year Project, PSCAD has been used as a tool for simulation to create a 200 km transmission line with circuit breaker and also a single line diagram of distance protection with Mho type distance relay in the transmission line. For those two transmission lines, some fault, like line-to-line fault, single line-to-ground fault, double line to ground fault had been created to the power transmission lines to see the output of the circuit and also to see the function or operation of the relay. Due to some software license problem, 2 different type of version for PSCAD has been used to run the simulation. PSCAD version 3.0.8 with license has only comparator relay, magnitude relay but no distance relay. Beside this, with the license, the software can support more the 15 nodes in 1 diagram.

For the single line diagram, distance protection is applied using PSCAD version 4.2.1 which is suitable for use in a distance protection. A simple line diagram with distance relay was being created. This simulation is to observe the distance relays reaction when a fault occurred in the transmission lines. More results and discussion will be done in the coming sub-topic of the thesis.

4.1 PSCAD version 3.0.8 Power Transmission Line Simulation

As mention just now, PSCAD version 3.0.8 has no distance relay. So the circuit that already been created had only circuit breaker to protected the power transmission line once a fault is occurred. This is a three phase diagram with the source of 230 kV phase value in rms, 50Hz. So the phase to ground value is 162.6kV. This transmission line is design with the length of 200km. For the first 80 km, there is a circuit breaker and also a control fault panel. So it mean that if want to see the output when there is a fault in 80 km, it can be created. Then follow by the 20km length, 50 km length and 50 km length power transmission lines. Every part of the length, there was a fault control panel. There were 10 different types of faults that can be created using this software. Beside that, the time fault start and time fault delay can also be set. Please refer to figure 12.

4.2 PSCAD version 4.2.1 Single Line Diagram

The distance protection single line diagram can be design by using this version. It was because this software had developed from time to time to add new components which could not find at version 3.0.8. For this software, if the software is a trial version, it cannot run a simulation that exist 15 nodes. So, due to license problem, a simple single line diagram can only be created out with only 14 nodes (Please refer to figure 13). The distance relays is control by system logic (Please refer to figure 14). Once there is a fault like line-to-ground fault or line-to-line fault occurred at the transmission line, the relay will trip according to the time setting. Then from the output wave form, it clearly show that once there is fault occurred, the wave form output will show some losses occurred in between the time fault start and the time fault delay.

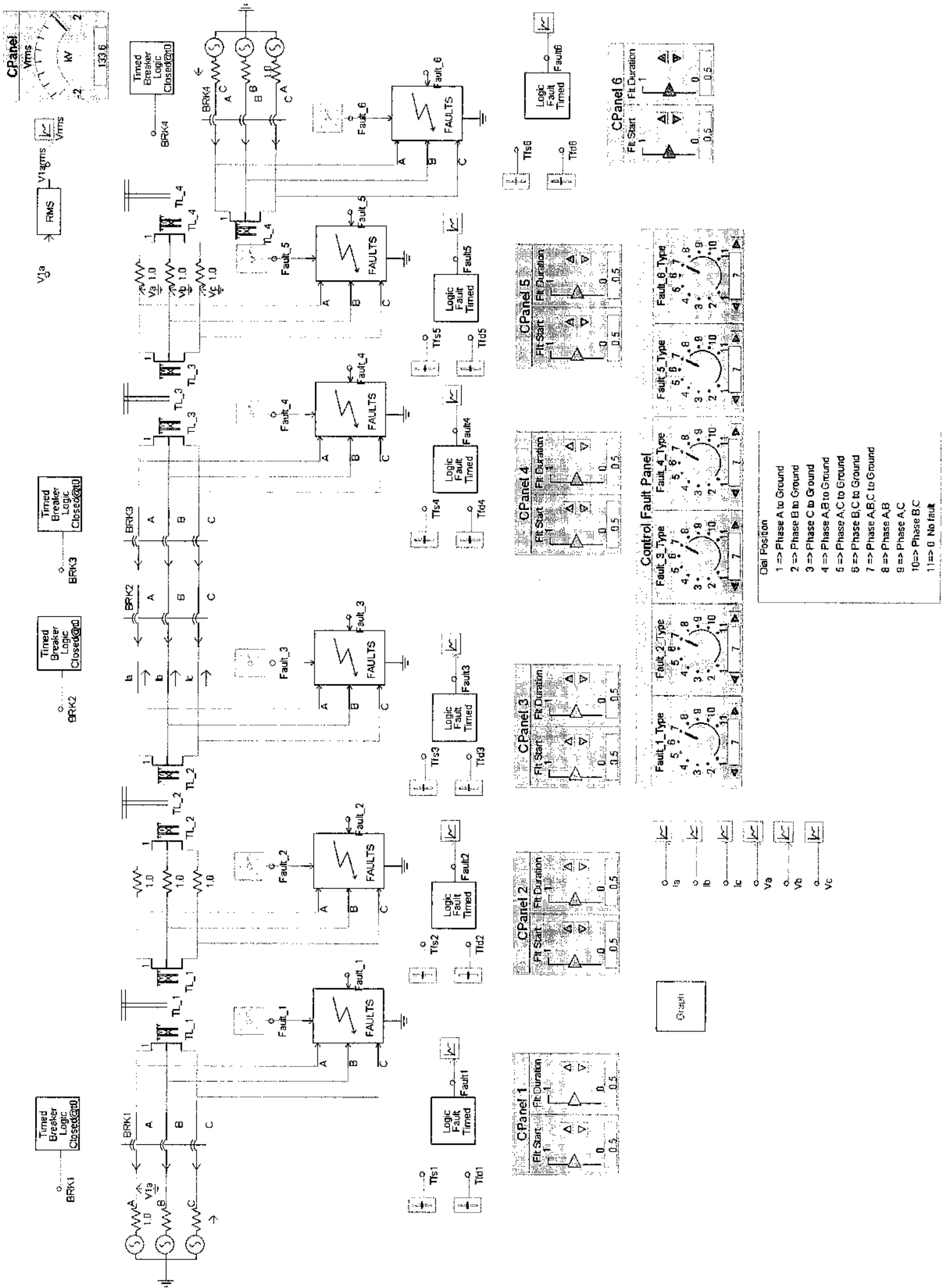


Figure 12: PSCAD version 3.0.8 Power Transmission Lines

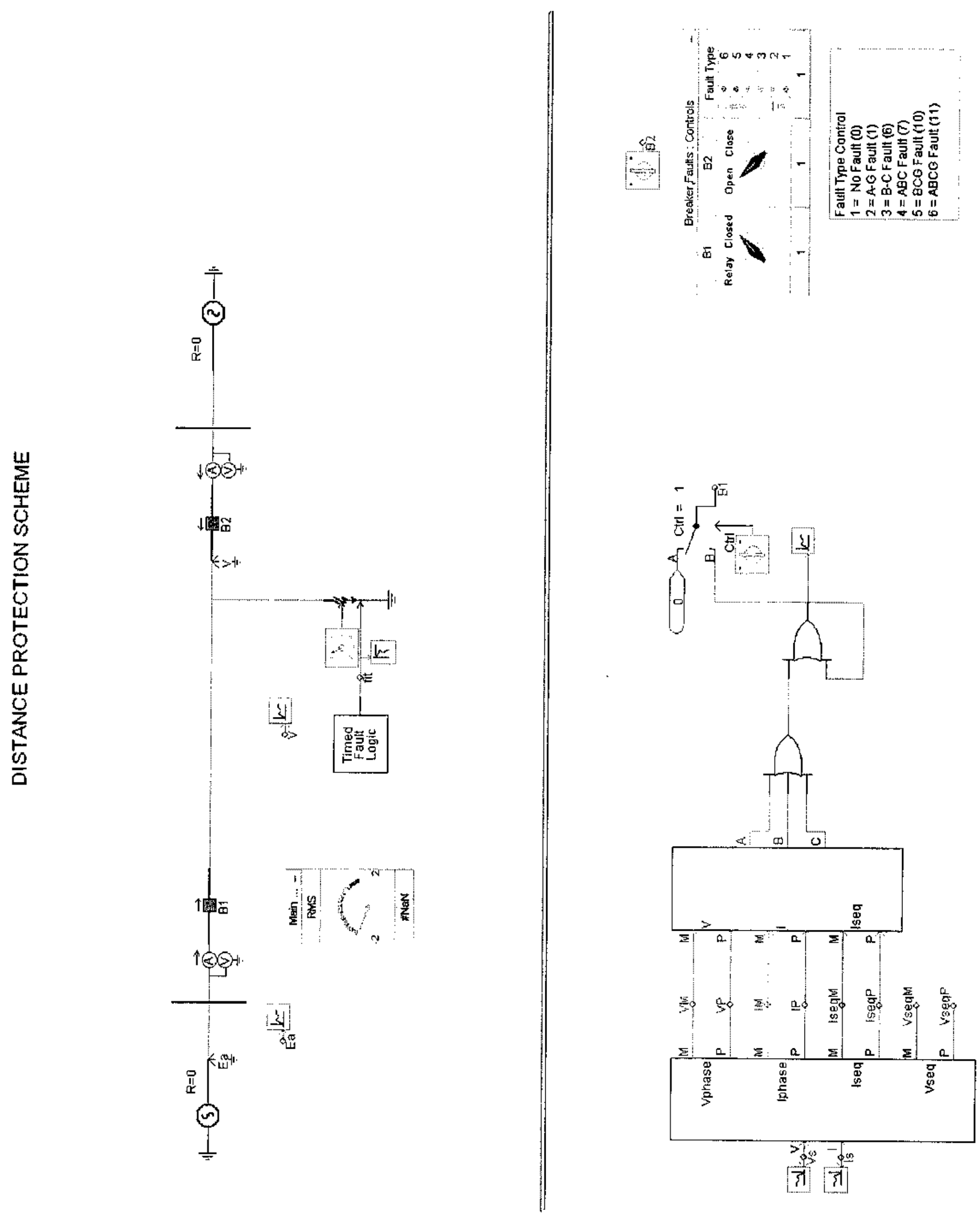


Figure 13: PSCAD version 4.2.1 Single Distance Protection Diagram

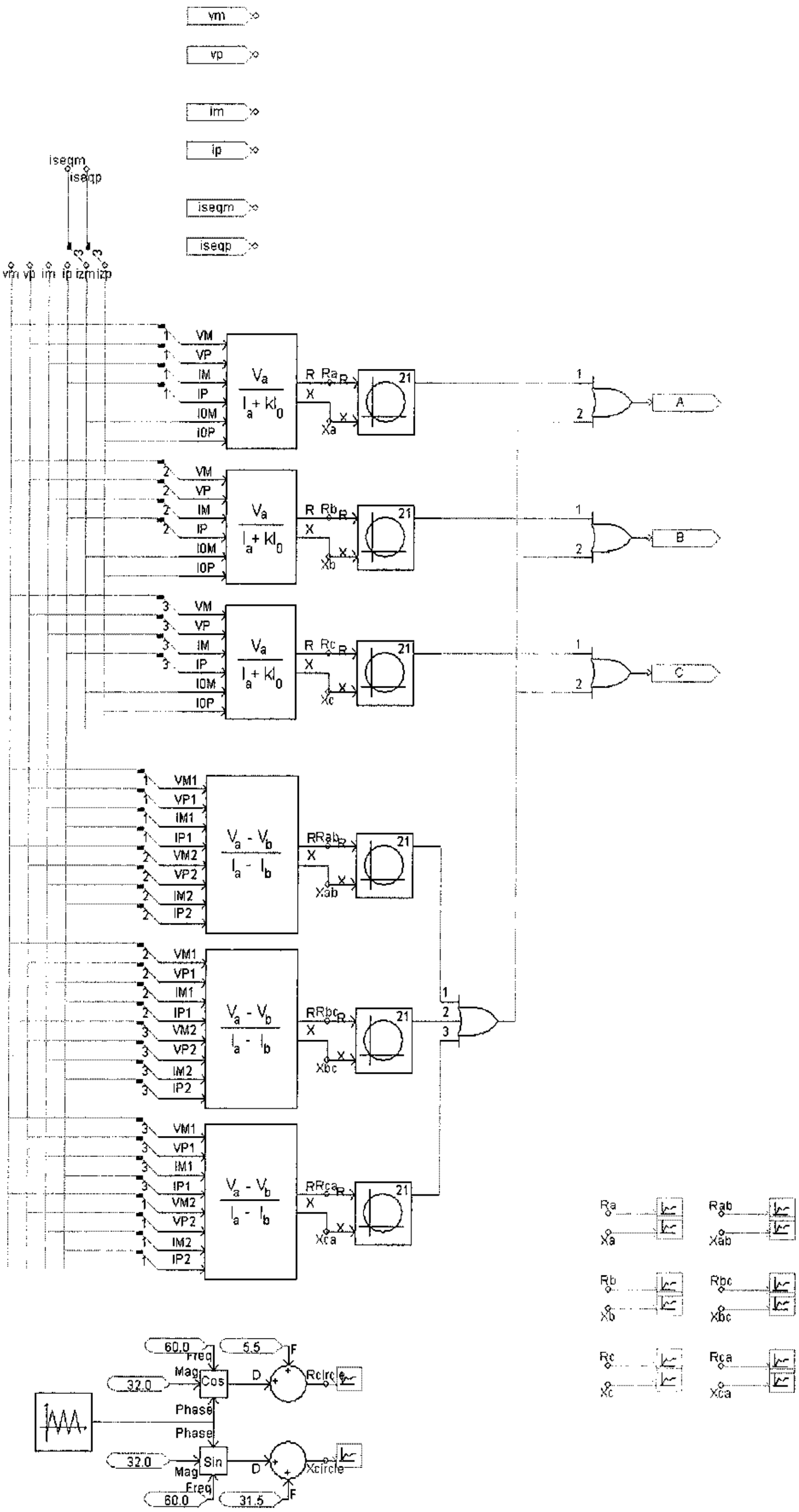


Figure 14: Distance Relay Diagram

4.3 PSCAD version 3.0.8 Simulation Results

4.3.1 Simulation Result from the 80 km Power Transmission Lines

From this 80 km power transmission lines simulation result, 4 type of different fault had been created on it. From the output of the waveform, it shows the different type of waveform. For the first fault (Figure 15), is Phase A to ground fault. From the output waveform, the Ia for phase A become abnormal. Meanwhile, Ib and Ic remain normal. From the voltage, it shows the Va is been cut off at the period of 0.4s. It was because the fault occurred at 0.4s.

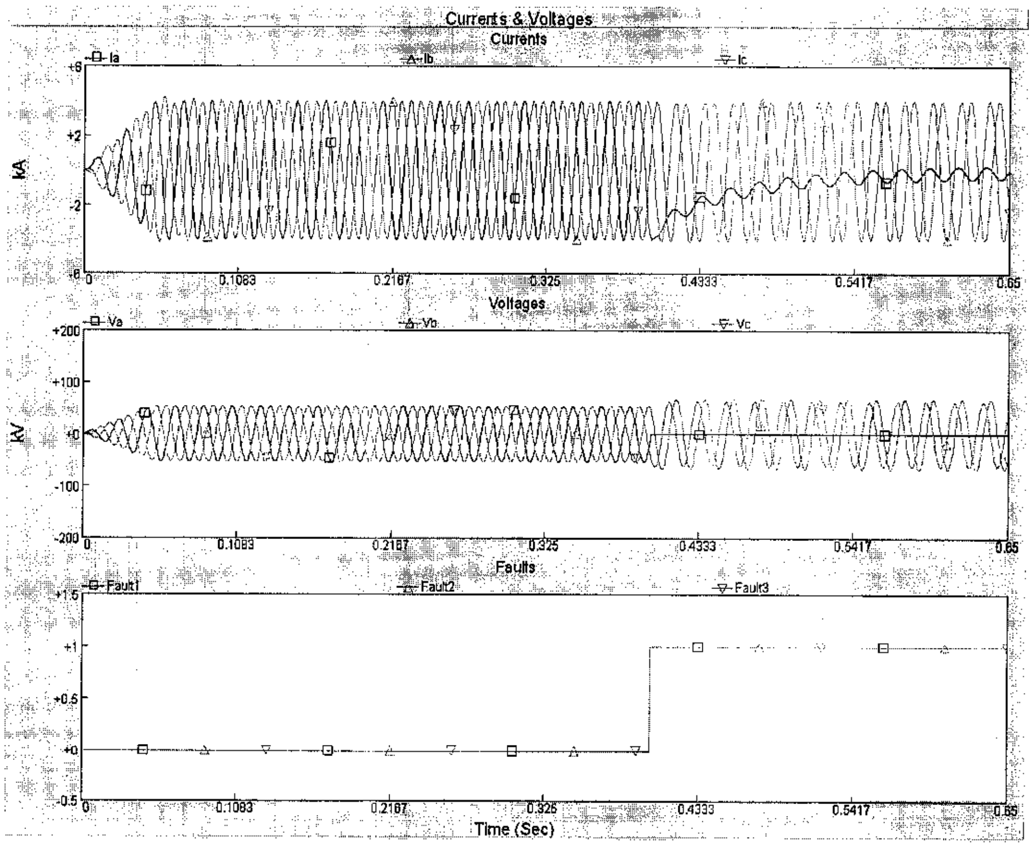


Figure 15: Phase A to Ground Fault

Refer to the Figure 16, a Phase A, B, C to Ground Fault had been created on the power transmission lines. Form the output waveform. It shows the fault occurred at 0.4s. So, the Ia, Ib, and Ic output waveform at 0.4s look abnormal. The current waveform from normal situation decrease becomes abnormal situation. For the Va, Vb, and Vc, the voltage had been cut off when a fault occurred at the fault period.

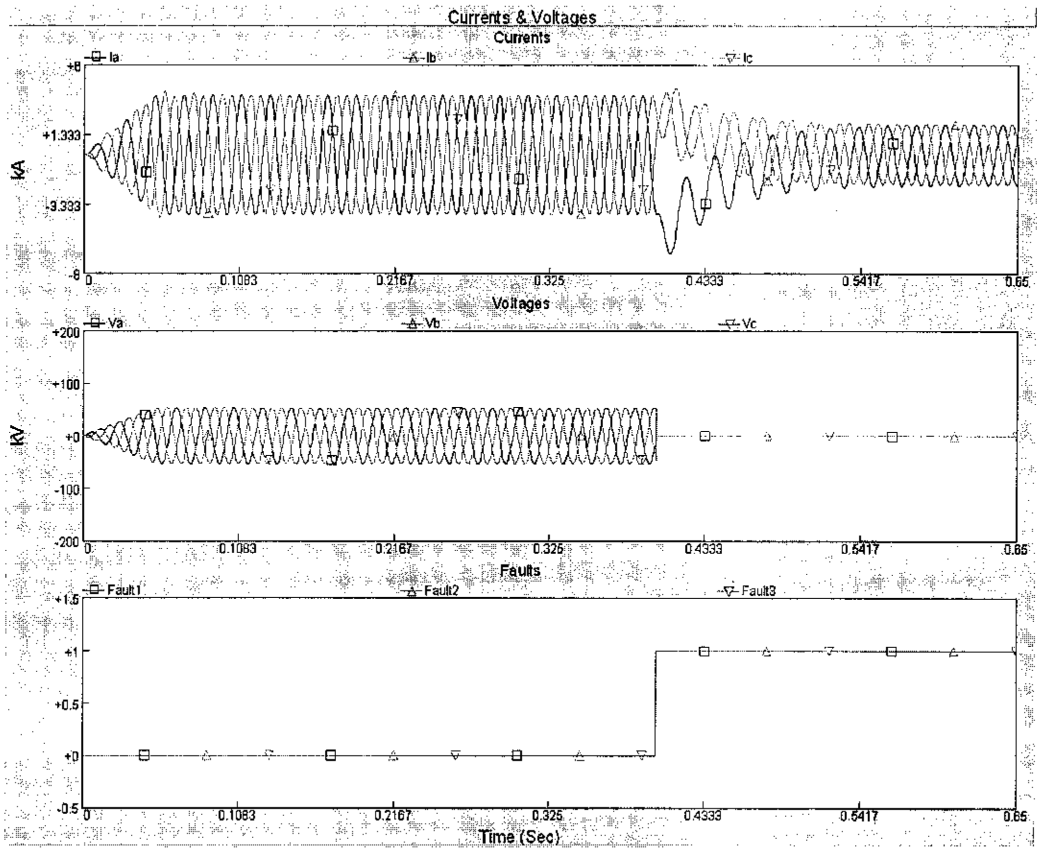


Figure 16: Phase A, B, C to Ground Fault

Refer to figure 17, the fault that occurred is phase A to phase C fault. From the output, Ia and Ic waveform suddenly increase in the 0.4s then decrease back. From the voltage, Va and Vc voltage decrease in the 0.4s. The fault period for this case is also 0.4s.

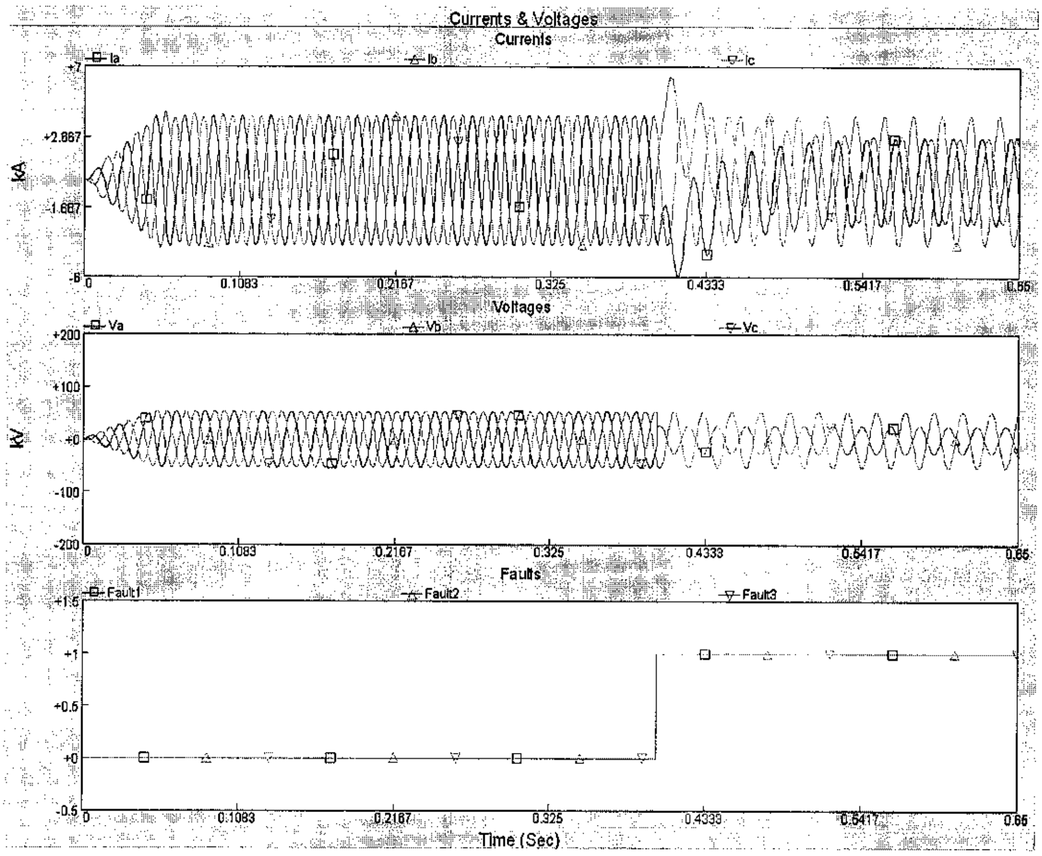


Figure 17: Phase A to Phase C Fault

4.3.2 Simulation Result from the first 100 km Power Transmission Lines

Figure 18 shows phase A to ground fault in the 100 km power transmission lines. Form the output, Ia waveform suddenly increase in the 0.4s and Va in 0.4s becme 0V. This is because the fault occurred in 0.4s.

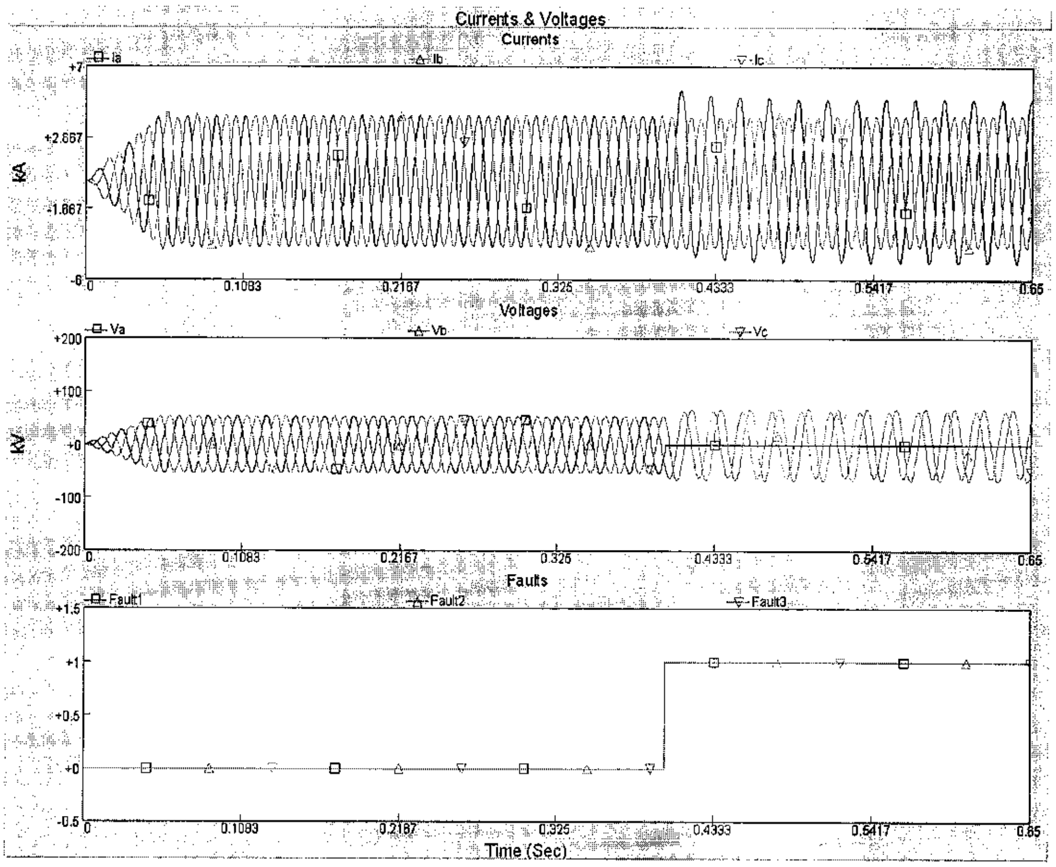


Figure 18: Phase A to Ground Fault

From the figure 19, a phase A, B, C to ground fault had occurred in the power transmission lines. The current values suddenly increase once the fault is occurred. For the voltage, Va, Vb and Vc voltage become 0V at the 0.4s. The start fault time is 0.4s.

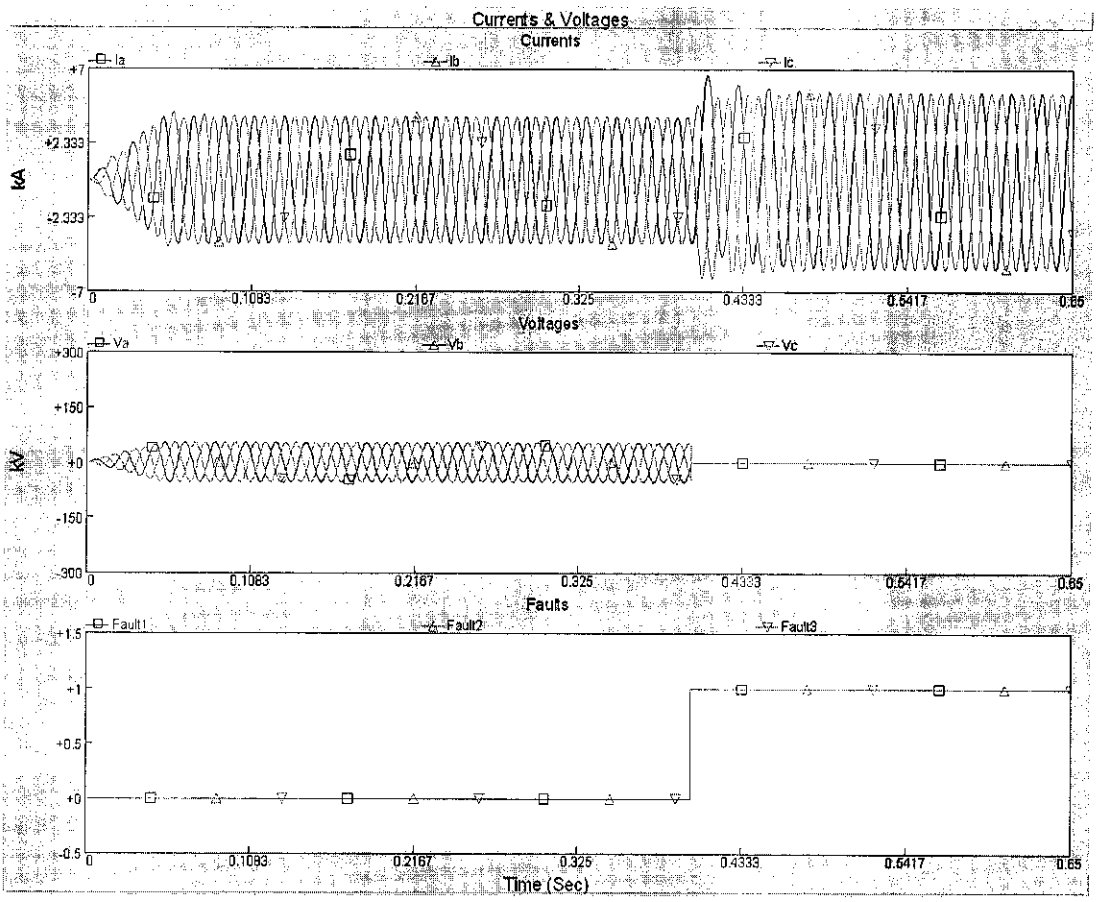


Figure 19: Phase A, B, C to Ground Fault

Figure 20 shows the phase A to phase B fault. When there is a fault occurred, Ia and Ib value suddenly increase. At the same time, the voltage for Va and Vb will decrease. The fault period is 0.4s.

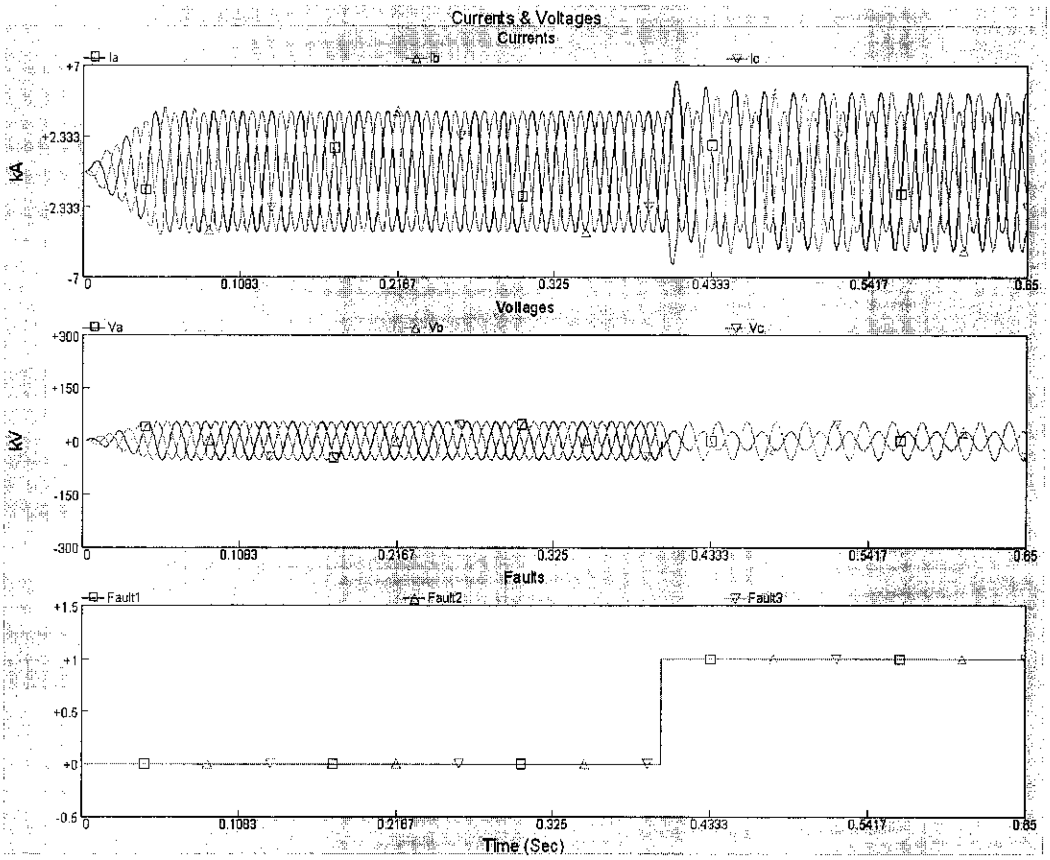


Figure 20: Phase A to Phase B Fault

4.4 PSCAD version 4.1.2 Simulation Results

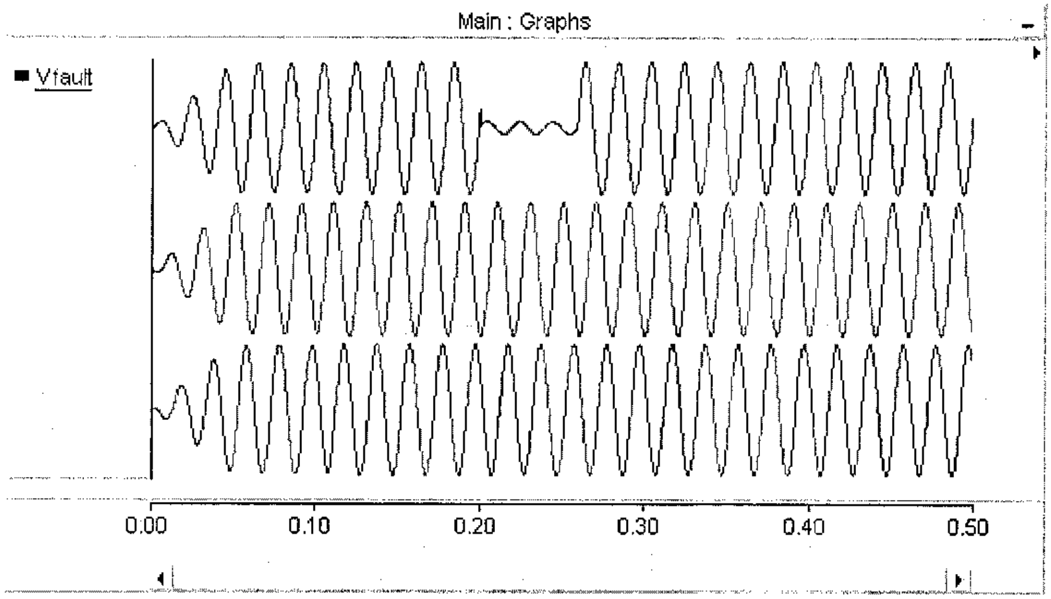


Figure 21: Phase A to Ground Fault

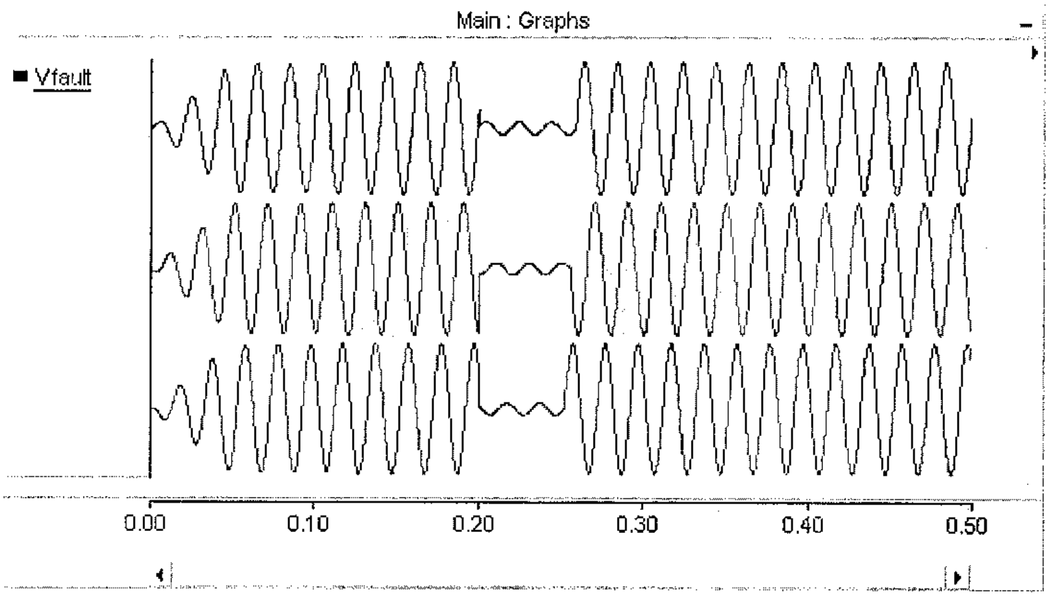


Figure 22: Phase A, B, C Fault

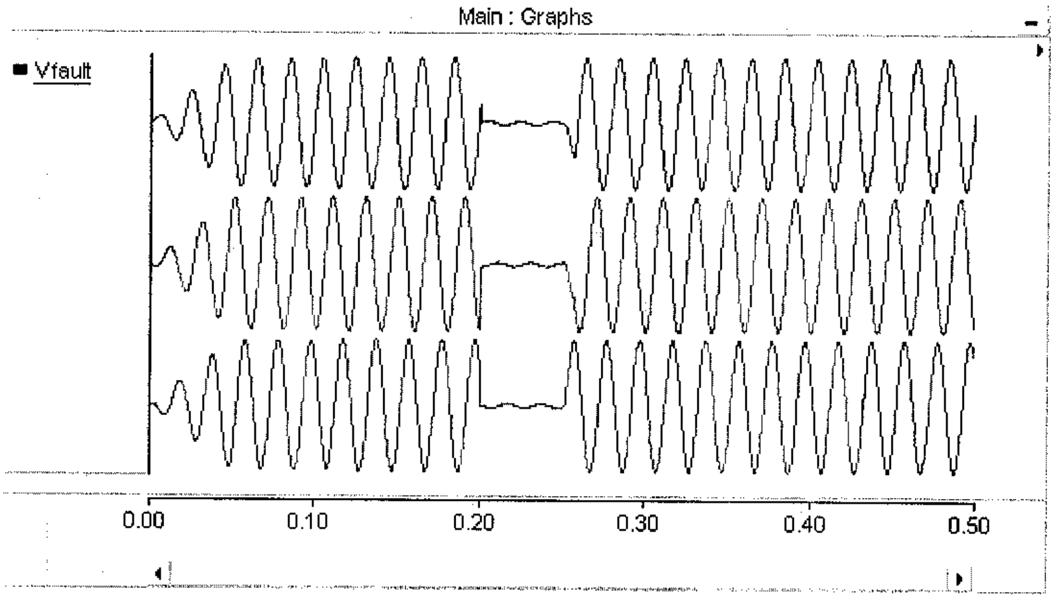


Figure 23: Phase A, B, C to Ground Fault

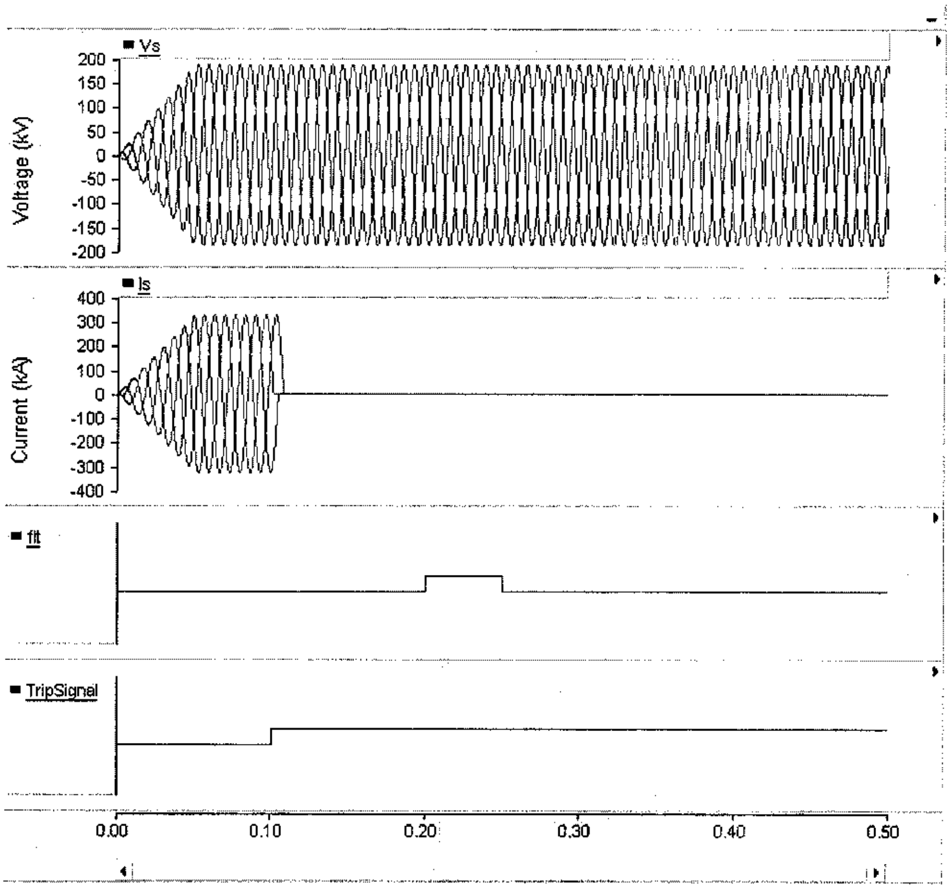


Figure 24: Signal Vs, Is and the Tripping Signal for Distance Relay

From the figure that shows in figure 21, figure 22 and figure 23 is the different type of fault that occurred in the power transmission PSCAD version 4.1.2. The start fault time is 0.2s. Figure 24 is the signal for the distance relays. Vs is the voltage input and Is is the current input. The distance relays trip period is set in 0.1s.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project serves as a framework that will enhance the students' skills in the process of applying knowledge, expanding thoughts and solving problems independently in addition to presenting these findings through qualified supervision.

A protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic and pessimistic approach to clearing system faults. For this reason, the technology and philosophies utilized in protection schemes are often old and well-established because they must be very reliable. Power systems protection is very important for everybody. It not only used to protect human being life, but it also protects our expensive equipments. There are five components usually used in the protection system likes batteries, relays, transducers, circuit breakers and bus configuration.

Although zone 3 of a step-distance protection scheme has been identified as one of the contributing causes of cascading failures in power systems, but it still the suitable method of distance protection that should provides protection for the distance protection scheme. Zone 3 protections can be removed, provided other equivalent protection by using pilot relays, or computer relays used to protect the circuit.

Distance protection performs a very important and essential part of many power protective relaying systems. Distance relay is one of the most popular types of protection employed for protective transmission lines. It can be set to operate for specific zones. Distance relay offers fast operating time (1 cycle). Besides that, it can work independently or co-ordination with other relay in the system. Distance relay can be easy to design and proven to be the best solution for wide range of system configuration.

The overall objectives of this project have been technically achieved. With the advance in the development of integrated approach, more sophisticated systems can be applied in the field of power system control and protection. Today's protection devices are ceasing to be confined to the protection of specific plant objects. Increasing demands on electricity supply, with the need for system economic optimization and power system growth limitations have a significant impact on power system reliability. Because of these system demands, the power system operates closer to its stability limits. Therefore a reliable power system is very important to restore the power system to normal operating condition in case of any system fault such as frequency instability, voltage instability and cascade tripping problem. The implementation of preventive operational strategies will undoubtedly reduce the risk of catastrophic large area disturbances.

5.2 Recommendation

It is recommended more sophisticated software like ATP (Alternative Transient Programme) can be used as the simulation tool. A more comprehensive protection system can be designed to protect the different types of faults in the power systems.

REFERENCES

[1] Volker Lohmann, "Wide Area Protection (WAP) A Strategy to Counteract Large Area Disturbances", ABB Power Automation Ltd., Baden/Switzerland, CHPAU/NS/VL 01.10.03

[2] Martin Geidl, "Protection of Power Systems with Distributed Generation: State of the Art", Power Systems Laboratory, Swiss Federal Institute of Technology (ETH) Zurich, 2005.

[3] S. H. Horowitz, and A. G. Phadke, "Third Zone Revisited", IEEE Transactions on Power Delivery, Vol. 21, No. 1, January 2006.

[4] *Distance Relays Fundamentals*, GE Power Management, MULTILIN, GER-3966.

[5] Chul-Hwan Kim, Jeong-Yong Heo, and Raj K. Aggarwal, "An nhanced Zone 3 Algorithm of a Distance Relay Using Transient Components and State Diagram", IEEE Transactions on Power Delivery, Vol. 20, No. 1, January 2005.

[6] S. H. Horowitz, A. G. Phadke, and J. S. Thorp, "Adaptive Transmission System Relaying", IEEE Transactions on Power Delivery, Vol. 3, No. 4, October 1988.

[7] A. G. Phadke, and J. S. Thorp, "Expose Hidden Failures to Prevent Cascading Outages", IEEE Computer Application in Power, July 1996.

[8] C. Tamronglak, S.H. Horowitz, A. G. Phadke, and J. S. Thorp, "Anatomy of Power System Blackouts: Preventive Relaying Strategies", IEEE Transactions on Power Delivery, Vol. 11, No. 2, April 1996.

WEBSITES

- http://www.mantatest.com/LineProtection.html
- www.google.com
- www.wikipedia.com
- www.howstuffwork.com
- www.engineering.com
- www.pscad.com
- www.**areva**-td.com/static/html/TDE-AGF_Product-Product_Detail1_1022750287782.html