Design and Simulation of Distance Relay on MATLAB/Simulink

B.E. (EE) PROJECT REPORT

by

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ABSTRACT

The aim of our project is to study the importance of Power System Protection and to design a scheme which provides an efficient and economical protection of transmission line using distance relay.

As there are many schemes available for protection having their own characteristics and importance such as over current, under voltage, under frequency and many more.

Different types of distance relays are available for protection including impedance type, reactance type and mho type. In our project, we focus on the impedance type distance relay. We have to simulate a model of transmission line and apply distance protection and study the current flow and change of impedance through the line .

DEDICATION

To our family and teachers who have been a source of inspiration for us throughout our life.

To our batch mates at NED who have challenged us, inspired us, encouraged us and made our university life memorable.

ACKNOWLEDGEMENTS

Our special gratitude is owed to ALLAH ALMIGHTY, with whose blessings we have been able to successfully accomplish our task.

Throughout our project, we received many different kinds of support and suggestions from many different people. We wish to acknowledge a number of these contributions.

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FUNDAMENTALS OF PROTECTION

INTRODUCTION

The purpose of an electrical power system is to generate and supply electrical energy to consumers. The system should be designed and managed to deliver this energy to the utilization points with both reliability and economy. Severe disruption to the normal routine of modern society is likely if power outages are frequent or prolonged, placing an increasing and economy are largely opposed.

Many items of equipment are very expensive, and so the complete power system represents a very large capital investment. To maximize the return on this outlay, the system must be utilized as much as possible within the applicable constraints of security and reliability of supply. More fundamental, however, is that the power system should operate in a safe manner at all times. No matter how well designed, faults will always occur on a power system, and these fault arc carrying a high current is very great, it can burn through copper conductors or weld together core laminations in a transformer or machine in a very short time, some tens or hundreds of milliseconds. Even away from the fault arc itself, heavy fault currents can cause damage o plant if they continue for more than a few seconds. The provision of adequate protection to detect and disconnect elements of the power system in the event of fault is therefore an integral part of power system design. Only by so doing can the objectives of the power system be met and the investment protected. This is the measure of the importance of protection system as applied in power system practice and of the responsibility vested in the protection engineer.

PROTECTION REQUIREMENTS

Protection for any power system must take into account the following principles:

1. The reliability of the system, the protection has the ability to operate correctly.
2. The speed, minimum operating time to clear a fault in order to avoid any damage to equipment.
3. The cost, maximum protection at the lowest cost possible.

PROTECTION CATEGORIES

Protection can be categorized into two categories;

1. Primary protection.
2. Back-up protection.

Primary Protection:

Primary protection should operate every time an element detects a fault on the power system. It can protect one or more components of the system, such as electrical machines, lines and bus –bars. In power system many primary protection devices are present.

Back-up Protection:

Back-up protection is installed to operate when the primary protection does not work for any reason. Thus back-up protection relay has the sensing element which may or may not similar to primary protection, the has the ability of time delay to slow down the operation of relay, thus allow primary protection to allow first.

PROTECTION AGAINST NATURE

Electrical power system is the most revolutionary invention on which now all the humans are dependent. As the span of the system spread to the common people for the consumption the need to make it reliable, effective and cheap increased. To make the system safer it is necessary to protect it from different faults.
In power system 70% to 90% of the faults are transient in nature and these faults occur when phase conductor electrically contact with other conductor or ground due to trees, birds or animals, high winds, lightning and flashovers, etc.
This factor produces transient faults. Transient faults can be cleared by using circuit breaker or fuses.

PROTECTION AGAINST FAULTS

In power system we are dealing with generators, transformers, motors or transmission lines. This all components are interconnected with each other by means of circuit breakers. So in practices we have seen that if faults occur to any of the component so our system may fail. So in order to avoid such accidents protection is required. The protection ensures that, in the event of a fault, the faulted element must be disconnected from the system for isolating the fault to prevent further damage to the components of the system. As the equipment used in the electrical system is very expensive, the re-installing of the damage equipments may rises to the cost effectiveness of the system. Therefore it is better to have a suitable protection system in order to save the equipments.

HOW TO CALCULATE A FAULT

A power system is normally treated as a balanced symmetrical three-phase network. When a fault occurs, the symmetry is normally upset, resulting in unbalanced currents and voltages appearing in the network.

For the correct application of protection equipment, it is essential to know the fault current distribution throughout the system and the voltages in different parts of the system due to the fault.

To obtain the above information, the limits of stable generation and possible operating conditions, including the method of system earthing, must be known. Fault are always assume to be through zero fault impedance

Fault calculations are basically of two types or in other words we can say that there could be two types of faults in an electric power system.

- Symmetrical fault
- Asymmetrical fault

SYMMETRICAL FAULTS

A symmetrical or balanced fault is a fault which affects each of the three-phases equally. In transmission line faults, roughly 5% are symmetric. This is in contrast to an asymmetric fault, where the three phases are not affected equally. In practice, most faults in power system are unbalanced. With this in mind, symmetric faults can be viewed as somewhat of an abstraction; however, as asymmetric faults are difficult to analyses, analysis of asymmetric fault is built up from a thorough understanding of symmetric fault

ANALYSIS:

Symmetric faults can be analyzed via the same methods as any other phenomena in power system, and in fact many software tools exist to accomplish this type of analysis automatically. However, there is another method which is as accurate and is usually more instructive

First, some simplifying assumptions are made. It is assumed that all electrical generators in the system are in phase, and operating at the normal voltage of the system. Electric motor can also be considered to be generators, because when a fault occurs, they usually supply rather than draw power. The voltages and currents are then calculated for this base case

Next, the location of the fault is considered to be supplied with a negative voltage source, equal to the voltage at that location in the base case, while all other sources are set to zero. This method makes use of the principle of superposition.

ASYMMETRICAL FAULTS

An asymmetrical or unbalanced fault is a fault which does not affect each of the three phases equally. This is in contrast to a symmetric fault, where each of the phases is affected equally. In practice, most faults in power system are unbalanced; however, as asymmetric faults are difficult to analyze, analysis of asymmetric fault is built up from a thorough understanding of symmetric faults.

Common types of asymmetric faults, and their causes:

- ✓ Line-to-line a short circuit between lines, caused by ionization of air, or when lines come into physical contacts, for example due to a broke insulator.
- ✓ Line-to-ground a short circuit between one line and ground, very often caused by physical contact, for example due to lightning or other storm damage.

- ✓ Double line-to-ground two lines came into contact with the ground (and each other), are commonly due to storm damage

ANALYSIS:

An asymmetric fault breaks the underlying assumptions used in three phase power, namely that the load is balanced on all three phases. Consequently, it is impossible to directly use tools such s\as the one-line diagram, where only one phase is consider the resulting voltages and currents as a superposition of symmetrical components, to which three phases analysis can be applied.

The method of symmetric components is, perhaps somewhat unintuitive, but can be verified to give correct results. The power system is seen as a superposition of three components:

A positive-sequence component, in which the phases are in the same order as the original system, i.e., a-b-c

A negative-sequence component, in which the phases are in the opposite order as the original system, i.e., a-c-b

A zero-sequence component, which is not truly phase system, but instead all three phases are in phase with each other

To determine the currents resulting from an asymmetrical fault, one must first know the per-unit zero-, positive-, and negative-sequence impedance of the transmission lines, generators, and transformers involved. Three separate circuits are then constructed using impedances.

The individual circuits are then connected together an in particular arrangement that depends upon the type of fault being studied. Once the sequence circuits are properly connected; the network can then be analyzed using classical circuit analysis techniques. The solution results in voltages and currents that exist as symmetrical components; these must be transformed back into phase values by using MATRIX.

HOW TO PROTECT OUR POWER SYSTEM

In electrical system protection has an important role; we can protect our electrical system by using different kinds of protection systems.

The different types of protection are listed below.

- Over-current protection.
- Over-load protection.
- Differential protection.
- Distance protection.
- Earth-fault protection.

Over-Current Protection:

Very high current in electrical system are usually due to the faults on the system. These currents can be used to determine the presence of faults and operate protective devices. Due to these currents the equipments which are installed might be damaged, so in order to avoid damages we need protection. Over current which is done by using OVER-CURRENT RELAYS? It is the most common form of protection used to deal with excessive currents on power system.

Over-Load Protection:

As our power system works on very high voltages a currents so their occurs heating problem in the system when they are over loaded for this purpose over-load protection is installed on power systems. It deals with thermal capacity of machines or lines.

Differential Protection:

The differential protection is done by connecting CT's across the differential relays on power system (or it can be done by using other relays). In this type protection we can protect our system or devices by means of currents entering or leaving the protected system, if the value of currents exceed through the pre-defined value thus differential relay will operate.

Earth-Fault Protection:

In electrical field earth or ground has several meanings depending on the specific application areas. Ground is the reference point in an electrical circuit from which other voltages are measured, a common return path for electric current (earth return or ground return), or a direct physical connection to the earth.
Electrical circuits may be connected to ground (earth) for several reasons. In power systems, a connection to ground are done for safety purposes to protect people from the effects of faulty insulation on electrically powered equipment. A connection to ground helps limit the voltage built in between power systems and the earth, protecting circuit insulation from damage due to excessive voltage.

Distance Protection:

Distance protection is a non-unit type of protection it can work by measuring the impedance of line. It has the ability to differentiate between the faults occurring on the system comparing the fault current sense by the relay against with voltage at relay location; if the value of impedance of line changes from the defined value; thus the relay will operate.

INTRODUCTION TO RELAYING SYSTEM

In a power system consisting of generators, transformers, transmission and distribution circuits, it is inevitable that sooner or later some fault will occur somewhere in the system. When a failure occurs on any part of the system, it must be quickly detected and disconnected from the system.

The detection of fault and disconnecting of faulty portion or apparatus can be achieved by using fuses or relays in conjunction with circuit breakers. A fuse perform both detection and interruption function automatically but its use is limited for the protection of low voltage level for about 3.3KV. The relay detects the fault and supply information to circuit breaker which perform the function of circuit interruption

PROTECTIVE RELAYS

A protective relay is a device that detects the fault and initiates the operation of the circuit breaker to isolate the detective element from the rest of the system

A relay detects the abnormal condition in the electrical circuit by constantly measuring the electrical quantities which are different under normal condition and faulty condition. The quantities which may change are voltage, current, frequency, and phase angle. Through the change in one of these or many will the fault signal appear and disconnect the faulty portion.

Relay circuit connection consist of three major parts

1. The primary winding of C.T which is connected in series of the line.
2. Secondary of C.T and the relay operating coil.
3. Tripping circuit which may be a.c or d.c.

FUNDAMENTAL REQUIREMENTS OF PROTECTIVE RELAYING

In order that protective relay system may perform this function satisfactorily, it should have following qualities

SELECTIVITY	RELIABILITY
SPEED	SIMPLICITY
SENSITIVITY	ECONOMY

SELECTIVITY

"It is the ability of the protected system to select correctly that part of the system in trouble and disconnect the faulty part without disturbing the rest of the system"

A well design and efficient relay system should be selective, it should be able to detect the point at which the fault occurs and cause the opening of the circuit breakers closest to the fault with minimum or no damage to the system.

SPEED

The relay system should disconnect the faulty portion as fast as possible for the following reasons:

1. Electrical apparatus may be damage if they carry the fault for a long time.

2. A failure on the system leads to a great reduction in voltage, if the faulty portion is not remove quickly then this will cause shut down in motor, generators and system become unstable.

SENSITIVITY

It is the ability of the relay system to operate with low value of actuating quantity

Sensitivity of a relay is a function of volt-ampere input to the coil of the relay necessary to cause its operation. The smaller the volt-amp input required causing relay operation, the more sensitive is the relay.

RELIABILITY

It is the ability of the relay system to operate under the pre-determined conditions. Without reliability, the protection would be rendered largely ineffective and could even become a liability.

SIMPLICITY

The relay system should be simple so that it can easily maintain. Reliability is closely related to simplicity. The simpler the protection system greater will be the reliability.

ECONOMY

The most important factor in the choice of a particular protection scheme is the economic aspect. Sometimes it is economically unjustified to use an ideal scheme of protection and a compromise method has to be adopted. As a rule, the protective gear should not cost more than 5% of the total cost.

RELAY TIMINGS

An important characteristic of a relay is its time of operation. Time operation me duration of time during the fault occurrence and the tripping of the relay some types of relays on time characteristic is discuss below;

INSTANTANEOUS RELAY

An instantaneous relay is the one in which no intentional time delay is provided. The instantaneous relays have operating time of 0.1 second. Whenever the current reaches the pickup value relay coil energized and operates the circuit breaker.

INVERSE TIME RELAY

An inverse time relay is one in which the operating time is approximately inversely proportional to the magnitude of the actuating quantity. At values of current lower than the pickup, the relay never operates. At higher value time of the relay decreases studiedly with the increase in current.
The inverse time characteristic can be also be obtained by connecting a time limit fuse in parallel with the trip coil.

DEFINITE TIME LAG RELAY

In this type of relay, there is a definite time elapse between the instant of pickup and the closing of relay contacts. This particular time setting in independent of the amount of current through the relay coil, being the same for all values of current in excess of the pickup value. It may be worthwhile to maintain here that practically all inverse time relay are also provided which definite minimum time feature in order that the relay may never become instantaneous in its action for very long overloads.

TYPES OF RELAYS ON THE BASIS OF PRINCIPLE OF OPERATION

Following are the two basic categories in which relays can be divided.

1. Electromagnetic relays.
2. Numeric relays

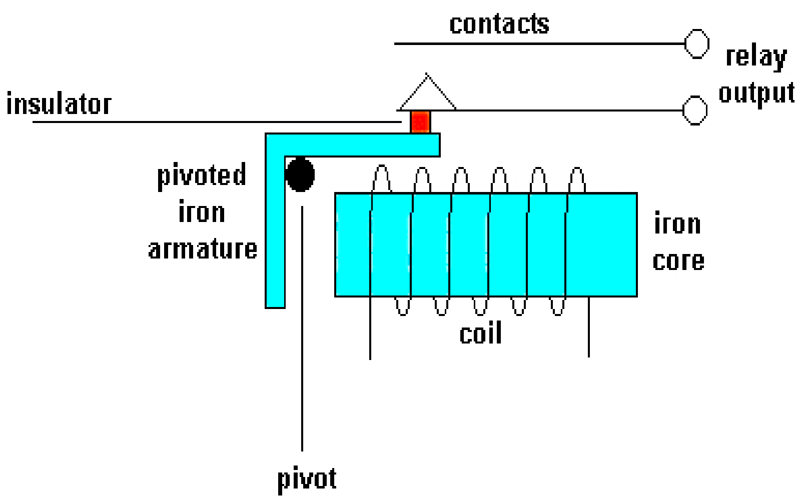
ELECTROMAGNETIC RELAY

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

CONSTRUCTION

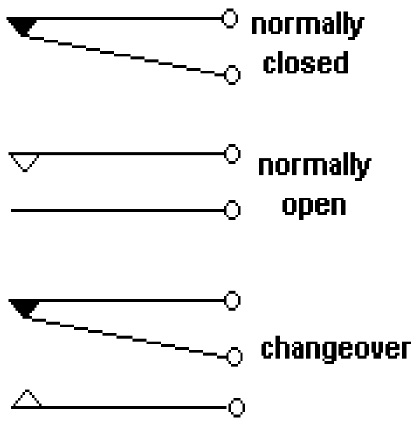
A simple electromagnetic relay consists of a coil of wire surrounding a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts (there are two in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the printed circuit board (PCB) via the yoke, which is soldered to the PCB.

WORKING PRINCIPLE:



1. When the coil is energized, by passing current through it, the core becomes temporarily magnetized.
2. The magnetized core attracts the iron armature.
3. The armature is pivoted which causes it to operate one or more sets of contacts.
4. When the coil is de-energized the armature and contacts are released.
5. The coil can be energized from a low power source such as a transistor while the contacts can switch high powers such as the mains supply.
6. The relay can also be situated remotely from the control source.
7. Relays can generate a very high voltage across the coil when switched off.
8. This can damage other components in the circuit.
9. To prevent this, diode is connected across the coil.

10. The spring sets (contacts) can be a mixture of N.O N.C and Common.
11. Various coil operating voltages (ac and dc) are available.
12. The actual contact points on the spring sets are available for high current and low current operation



TYPES OF ELECTROMAGNETIC RELAYS

Electromagnetic attraction relays operate by virtue of an armature being attracted to the pole of an electromagnet or a plunger being drawn into a solenoid. Such relays may be actuated by d.c or a.c. quantities. The important types of electromagnetic attraction relays are:

- **Attracted Armature Type Relay:**

Armature type relay consist of a laminated electromagnet, carrying a coil and a pivoted laminated armature. The armature is balanced by a counterweight and carries a pair of spring contact fingers at its free end. Under normal condition, the current through the coil relay coil is such that counterweight holds the armature in the position shown.
However when a short circuit occurs, the current through the relay coil increases sufficiently and relay armature is attracted upward. The contacts on relay armature bridge a pair of stationary contacts attached to the relay frame. This completes the trip circuit which results in the opening of the circuit breaker and therefore it disconnect the faulty portion.

- **Solenoid Type Relay:**

Solenoid type relay consist of a movable iron plunger . Under normal operating condition the current through the coil is such that it holds the plunger by gravity or spring in the position shown. However, on the occurrence of a fault, the current through the relay coil becomes more then the pickup value, causing the plunger to be attracted to the solenoid. The upward movement of the plunger closes the trip circuit , thus opening the circuit breaker and disconnect the faulty circuit.

➢ Balance Beam Type Relay:

It consists of an iron road armature fastened to a balance beam. Under normal operating condition the current through the relay coil is such that the beam is held in the horizontal position by the spring. However, when a fault occurs, the current through the relay coil become greater than the pickup value and the beam is attracted to close the trip circuit. This causes the opening of the circuit breaker to isolate the faulty circuit.

NUMERIC RELAYS

Modern power system protection devices are built with integrated functions. Multi-functions like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer. Traditionally, electromechanical and static protection relays offered single-function, single characteristics, whereas modern numeric protection offers multi-function and multiple characteristics. Some protections also offer adaptable characteristics, which dynamically change the protection characteristic under different system conditions by monitoring the input parameters.

First generation numerical relays were mainly designed to meet the static relay protection characteristic, whereas modern numeric protection devices are capable of providing complete protection with added functions like control and monitoring. Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information. Numerical protection devices are available for generation, transmission and distribution systems.

OPERATION

The digital protective relay, or numeric relay, is a microprocessor to analyze power system voltages and currents for the purpose of detection of faults in an electric power system. Tripping decisions are not made by any measuring elements but are done by Micro-Computers who continuously calculate and monitor the system data. General characteristics of a digital protective relay include:

1. The relay applies A/D (analog-to-digital) conversion processes to the incoming voltages and currents.

2. The relay analyzes the A/D converter output to extract, as a minimum, magnitude of the incoming quantity; commonly using Fourier transform concepts (RMS and some form of averaging are used in basic products). Further, the Fourier transform is commonly used to extract the signal's phase angle relative to some reference, except in the most basic applications.

3. The relay is capable of applying advanced logic. It is capable of analyzing whether the relay should trip or restrain from tripping based on current and/or voltage magnitude (and angle in some applications), parameters set by the user, relay contact inputs, and in some applications, the timing and order of event sequences.

4. The logic is user-configurable at a level well beyond simply changing front panel switches or moving of jumpers on a circuit board.

5. The relay has some form of event recording. The event recording would include some means for the user to see the timing of key logic decisions, relay I/O (input/output) changes, and see in an oscillographic fashion at least the fundamental frequency component of the incoming AC waveform.

6. The relay has an extensive collection of settings, beyond what can be entered via front panel knobs and dials, and these settings are transferred to the relay via an

interface with a PC (personal computer), and this same PC interface is used to collect event reports from the relay.

7. More complex digital relays will have metering and communication protocol ports, allowing the relay to become an element in a SCADA system.

By contrast, an electromechanical protective relay converts the voltages and currents to magnetic and electric forces and torques that press against spring tensions in the relay. The tension of the spring and taps on the electromagnetic coils in the relay are the main processes by which a user sets such a relay. In a solid state relay, the incoming voltage and current waveforms are monitored by analog circuits, not recorded or digitized. The analog values are compared to settings made by the user via potentiometers in the relay, and in some case, taps on transformers.

In some solid state relays, a simple microprocessor does some of the relay logic, but the logic is fixed and simple. For instance, in some time overcurrent solid state relays, the incoming AC current is first converted into a small signal AC value, and then the AC is fed into a rectifier and filter that converts the AC to a DC value proportionate to the AC waveform. An op-amp and comparator is used to create a DC that rises when a trip point is reached. Then a relatively simple microprocessor does a slow speed A/D conversion of the DC signal, integrates the results to create the time-overcurrent curve response, and trips when the integration rises above a set point. Though this relay has a microprocessor, it lacks the attributes of a digital/numeric relay, and hence the term.

BASIC PRINCIPLE:

Low voltage and low current signals (i.e., at the secondary of a Voltage transformers and Current transformers) are brought into a low pass filter that removes frequency content above about 1/3 of the sampling frequency (a relay A/D converter needs to sample faster than 2x per cycle of the highest frequency that it is to monitor). The AC

signal is then sampled by the relay's analog to digital converter at anywhere from about 4 to 64
(Varies by relay) samples per power system cycle. In some relays, the entire sampled data is kept for oscillographic records, but in the relay, only the fundamental component is needed for most protection algorithms, unless a high speed algorithm is used that uses sub cycle data to monitor for fast changing issues. The sampled data is then passed through a low pass filter that numerically removes the frequency content that is above the fundamental frequency of interest (i.e., nominal system frequency), and uses Fourier transform algorithms to extract the fundamental frequency magnitude and angle. Next the microprocessor passes the data into a set of protection algorithms, which are a set of logic equations in part designed by the protection engineer, and in part designed by the relay manufacturer, that monitor for abnormal conditions that indicate a fault. If a fault condition is detected, output contacts operate to trip the associated circuit breaker(s).

ADVANTAGES

- Highly economical
- More availability
- Less work at panel fabrication
- Highly flexible in use
- Memory
- Possibility of Remote Control.
- Possibility of down loading the information.

COMPARISON

NUMERIC RELAYS

ELECTROMAGNETIC RELAYS

Self-monitoring of
No self-monitoring.

hardware and software.

Highly flexible in use.
Not flexible in use. (Original design

(Rated current can be changed as well as characteristics can be chosen as per req.)

Settings through local or remote desktop.
Settings through local knobs and links

possible

Less work at panel fabrication.

Highly economical as well as robust.

characteristics cannot be changed).

DISTANCE RELAYS

The fundamentals of protective relaying of EHV transmission lines such as 220kV is to ensure secure protection for all line's internal faults, and stable operation for all foresee-able external faults during system contingencies. This provides an overview of how utilities have traditionally applied distance protection relays for protecting EHV Transmission Lines. These traditional methods cover most aspects of the protection and control of EHV lines, however these methods lack in performance when they are subjected to actual power system and fault conditions.

It also compares the findings of a real time closed loop study against with traditional methods of protecting and controlling a 220 kV EHV transmission line, and provides guidelines to ensure dependable performance of distance protective relays during dynamic system conditions.

Protective relaying is both "Art and Science". The proper relaying scheme for EHV Transmission Lines can be influenced by a number of factors such as transmission line voltage level, length, proximity to generation sources, load flows, stabilities studies etc. Performing setting calculations of Transmission Line protection relays always offers a challenging opportunity to protection and control engineers who examine many fundamental relaying considerations that apply, in one degree or another, to the protection of other types of power system equipment

Distance relay works by measuring the amount of impedance (Z), and transmission is divided into several areas of security coverage of Zone-1, Zone-2, and Zone-3, and equipped also with Tele-Protection (TP) in a bid for protection work is always fast and selective inside the security area.

WORKING PRINCIPLE

- Distance relay measures voltage and current at the point of visible disruption of the relay, by dividing the amount of voltage and current, the impedance to the point of interference can be determined.

- The calculation of the impedance can be calculated using the following formula:

  $$Zf = (Vf / If)$$

  Where:

  Zf = Impedance (ohm)

  Vf = Voltage (Volts)

  If = Flow disturbance

Distance relay will work by comparing the measured impedance interference with impedance settings, with the following provisions:

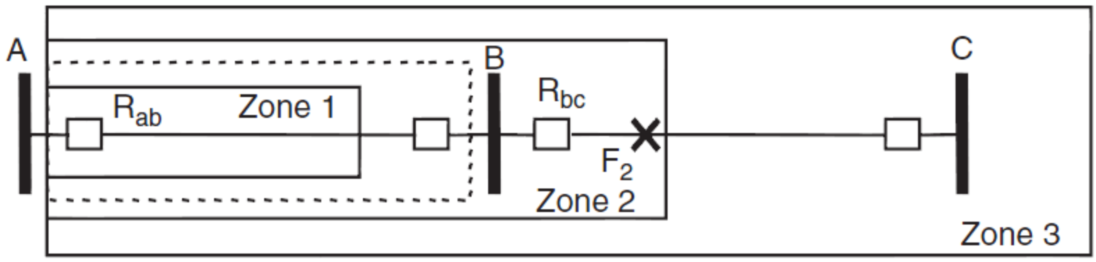
a) When the price of disorder impedance is smaller than the impedance setting of the relay then the relay will trip.

b) If the price of disorder is greater than the impedance setting of the relay then the relay will not trip.

STEPPED DISTANCE PROTECTION

Before describing the specific application of stepped distance protection, the definitions of under reach and overreach must be addressed. ‘Underreaching’ protection is a form of protection in which the relays at a given terminal do not operate for faults at remote locations on the protected equipment. This definition states that the relay is set so that it will not see a fault beyond a given distance.

The distance relay is set to underreach the remote terminal. The corollary to this definition, of course, is that the relay will see faults less than the setting. ‘Overreaching’ protection is a form of protection in which the relays at one terminal operate for faults beyond the next terminal. They may be constrained from tripping until an incoming signal from a remote terminal has indicated whether the fault is beyond the protected line section.2 Note the added restriction placed on overreaching protection to avoid loss of coordination. The zone of distance relays is open at the far end. In other words, the remote point of reach of a distance relay cannot be precisely determined, and some uncertainty about its exact reach must be accepted. This uncertainty of reach is typically about 5% of the setting. Referring to the desired zone of protection is shown with a dotted line. The ideal situation would be to have all faults within the dotted area trip instantaneously. Owing to the uncertainty at the far end, however, to be sure that we do not overreach the end of the line section, we must accept an under reaching zone (zone 1). It is customary to set zone 1 between 85% and 90% of the line length and to be operated instantaneously.



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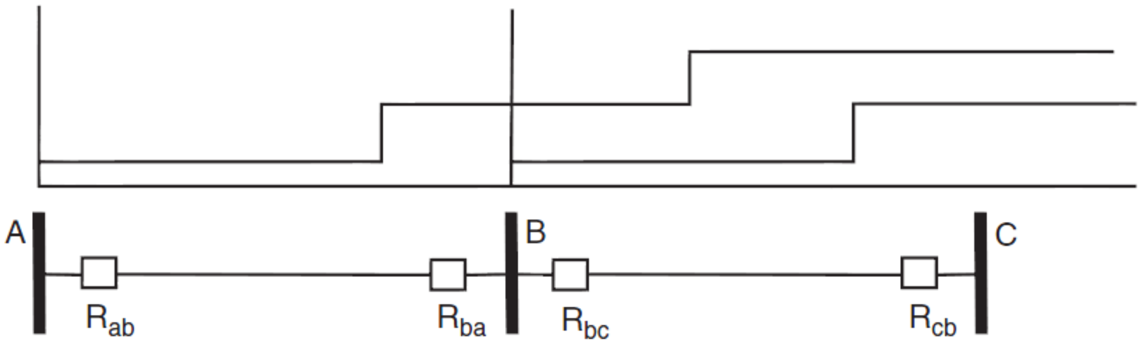


It should be clear that zone 1 alone does not protect the entire transmission line: the area between the end of zone 1 and bus B is not protected. Consequently, the distance relay is equipped with another zone, which deliberately overreaches beyond the remote terminal of the transmission line. This is known as zone 2 of the distance relay, and it must be slowed down so that, for faults in the next line section, zone 1 of the next line is allowed to operate before zone 2 of the distance relay at A. This coordination delay for zone 2 is usually of the order of 0.3 s, the reach of the second zone is generally set at 120%–150% of the line length AB. It must be brought in mind that zone 2 of relay Rab must not reach beyond zone 1 of relay Rbc, otherwise some faults may exist simultaneously in the second zones of Rab and Rbc, and may lead to unnecessary tripping of both lines. This concept, of coordination by distance as well as by time, leads to a nesting of the zones of protection.

It should be noted that the second zone of a distance relay also backs up the distance relay of the neighboring line. However, this is true for only part of the neighboring line, depending upon how far the second zone reaches. In order to provide a backup function for the entire line, it is customary to provide yet another zone of protection for the relay at A. This is known as the third zone of protection, and usually extends to 120%–180% of the next line section. The third zone must coordinate in time and distance with the second zone of the neighboring circuit, and usually the operating time of the third zone is of the order of 1 s. The three zones of protection of the two line sections AB and BC are shown in the above figure. It should also be mentioned that it is not always possible to have acceptable settings for the two overreaching zones of distance relays. Many of these issues will be discussed in greater detail in later sections. However, it is worth noting some of the limiting causes at this time. First, a complication is caused by dissimilar lengths of adjacent lines. If the length of a downstream line is less than 20% of the line being protected, its zone 2 will certainly overreach the first zone of the shorter line. Similarly, the zone 3 of the first line may overreach the zone 2 of the next line. The guidelines for setting the reach of zones mentioned above must be considered to be approximate, and must be adjusted to meet a specific situation at hand. Zone 3 was originally applied as a remote backup to zones 1 and 2 of an adjacent line in the event that a relay or breaker failure prevented clearing the fault locally.3 The reach setting, however, is a complex problem and is the subject of many ongoing studies and suggestions which will be discussed in detail in. However, the zone 3 characteristic must provide protection against faults but should not operate for normal, system conditions such as heavy loads or stability swings. Computer relaying makes provision for identifying heavy loads or stability swings through its load encroachment feature. Another consideration is the effect of the fault current contributions from lines at the intermediate buses.

THE IMPEDANCE-TYPE DISTANCE RELAY

Since this type of relay involves impedance-type units, let us first become acquainted with them. Generally speaking, the term “impedance” can be applied to resistance alone, reactance alone, or a combination of the two. In protective-relaying terminology, however, an impedance relay has a characteristic that is different from that of a relay responding to any component of impedance. And hence, the term “impedance relay” is very specific. In an impedance relay, the torque produced by a current element is balanced against the torque of a voltage element. The current element produces positive (pickup) torque, whereas the voltage element produces negative (reset) torque. In other words, an impedance relay is a voltage-restrained over current relay. If we let the control-spring effect be -K3, the torque equation is:

$$T = K_1 I^2 - K_2 V^2 - K_3$$

where I and V are rms magnitudes of the current and voltage, respectively. At the balance point, when the relay is on the verge of operating, the net torque is zero, and

$$K_2 V^2 = K_1 I^2 - K_3$$

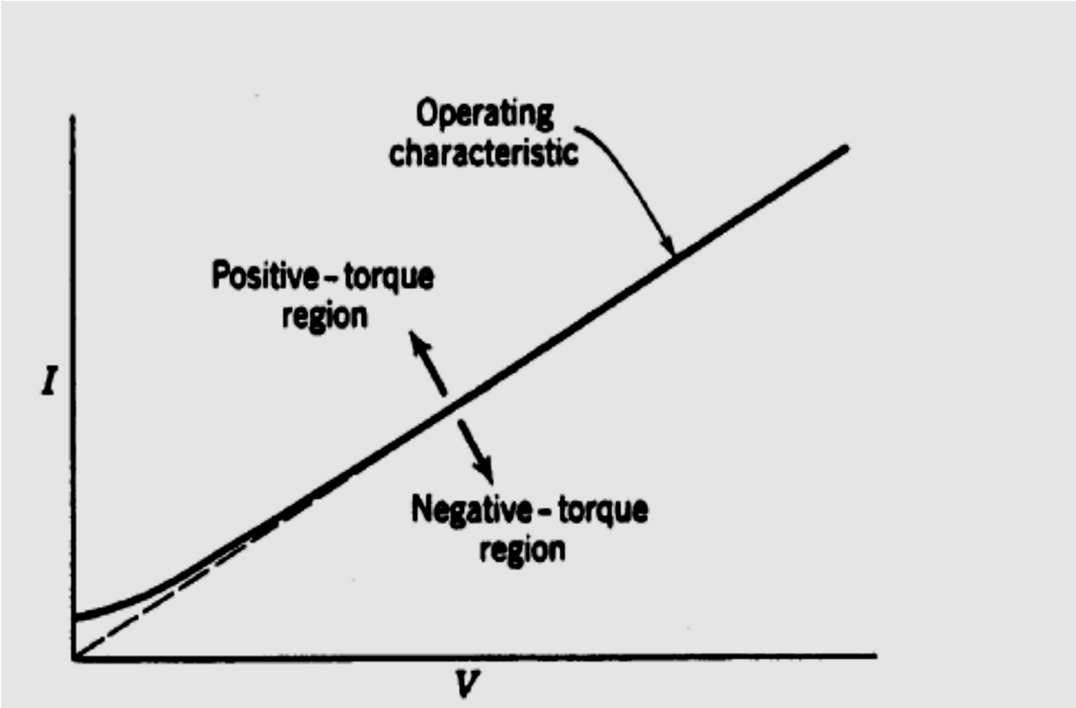
It is customary to neglect the effect of the control spring, since its effect is noticeable only at current magnitudes well below those normally encountered. Consequently, if we let K3 be zero, the preceding equation becomes

$$\frac{V^2}{I^2} = \frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}$$

$$\frac{V}{I} = Z = \sqrt{\frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}}$$

$$Z = \sqrt{\frac{K_1}{K_2}} = \text{constant}$$

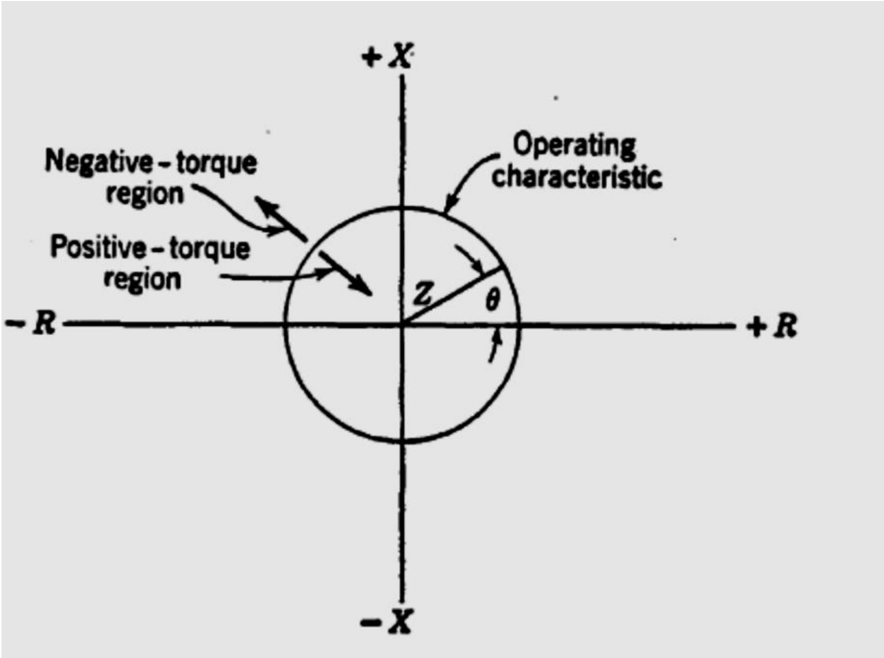
In other words, an impedance relay is on the verge of operating at a given constant value of the ratio of V to I, which may be expressed as an impedance. The operating characteristic in terms of voltage and current is shown in Fig. l, where the effect of the control spring is shown as causing a noticeable bend in the characteristic only at the low-current end. For all practical purposes, the dashed line, which represents a constant value of Z, may be considered the operating characteristic. The relay will pick up for any combination of V and I represented by a point above the characteristic in the positive-torque region, or, in other words, for any value of Z less than the constant value represented by the operating characteristic. By adjustment, the slope of the operating characteristic can be changed so that the relay will respond to all values of impedance less than any desired upper limit.



Operating characteristic of an impedance relay.

A much more useful way of showing the operating characteristic of distance relay is by means of the so-called “impedance diagram” or “R-X diagram” Reference 1 provides a comprehensive treatment of this method of showing relay characteristics. The operating characteristic of the impedance relay, neglecting the control-spring effect.

The numerical value of the ratio of V to I is shown as the length of a radius vector, such as Z, and the phase angle q between V and I determines the position of the vector, as shown. If I is in phase with V, the vector lies along the +R axis; but, if I is 180 degrees out of phase with V, the vector lies along the -R axis.



Operating characteristic of an impedance relay on an R-X diagram.

If I lags V, the vector has a +X component; and, if I leads V, the vector has a -X component. Since the operation of the impedance relay is practically or actually independent of the phase angle between V and I, the operating characteristic is a circle with its center at the origin. Any value of Z less than the radius of the circle will result in the production of positive torque, and any value of Z greater than this radius will result in negative torque, regardless of the phase angle between V and I.

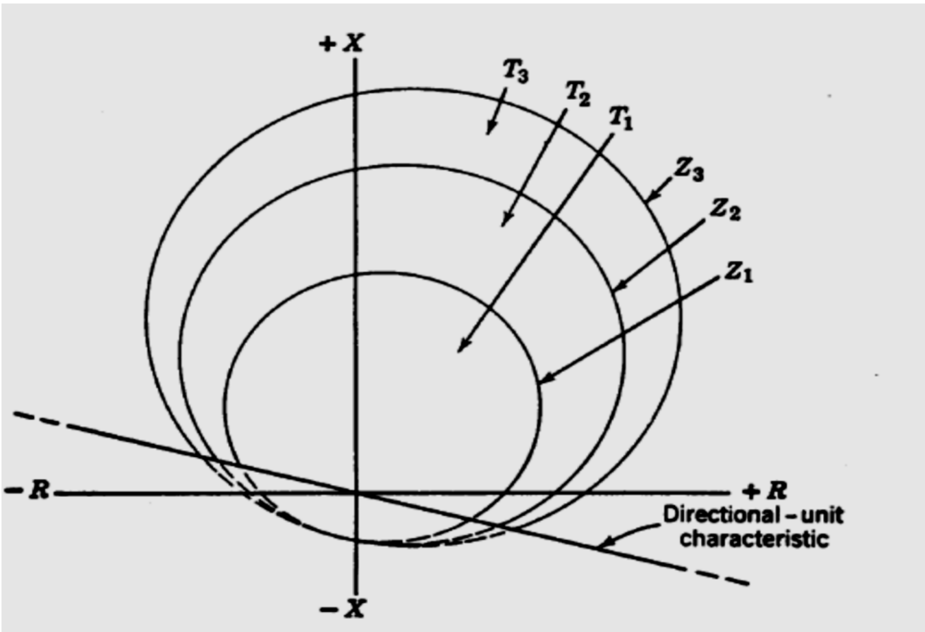
THE MODIFIED IMPEDANCE-TYPE DISTANCE RELAY

The modified impedance-type distance relay is like the impedance type except that the impedance-unit operating characteristics are shifted, this shift is accomplished by what is called a “current bias”, which merely consists of introducing into the voltage supply an additional voltage proportional to the current square, making the torque

Equation as follows

$$T = K_1 I^2 - K_2 (V + CI)^2$$

The term (V + CI) is the rms magnitude of the vector addition of V and CI, involving the angle q between V and I as well as a constant angle in the constant C term. This is the equation of a circle whose center is offset from the origin, as shown in. By such biasing, a characteristic circle can be shifted in any direction from the origin, and by any desired amount, even to the extent that the origin is outside the circle. Slight variations may occur in the biasing, owing to saturation of the circuit elements.



For this reason, it is not the practice to try to make the circles go through the origin, and therefore a separate directional unit is required as indicated in. Since this relay is otherwise like the impedance-type relay already described.

THE REACTANCE TYPE DISTANCE RELAY

The reactance-relay unit of a reactance-type distance relay has, in effect, an over current element developing positive torque, and a current-voltage directional element that either opposes or aids the over current element, depending on the phase angle between the current and the voltage. In other words, a reactance relay is an over current relay with directional restraint. The directional element is arranged to develop maximum negative torque when its current lags its voltage by 90°. The induction-cup or double-induction-loop structures are best suited for actuating high-speed relays of this type. If we let the control-spring effect be -K3, the torque equation is:

$$T - K_1 I^2 - K_2 VI \sin\theta - K_3$$

At the balance point, the net torque is zero,
and hence;

$$K_1 I^2 - K_2 VI \sin\theta + K_3$$

Dividing both sides of the equation by I2, we get:

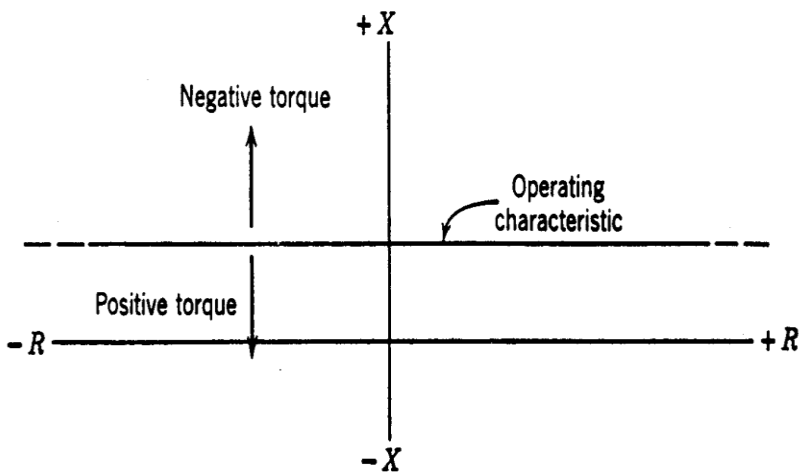
$$K_1 - K_2 \frac{V}{I} \sin\theta + \frac{K_3}{I^2}$$

$$\frac{V}{I}\sin\theta - Z\sin\theta - X - \frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}$$

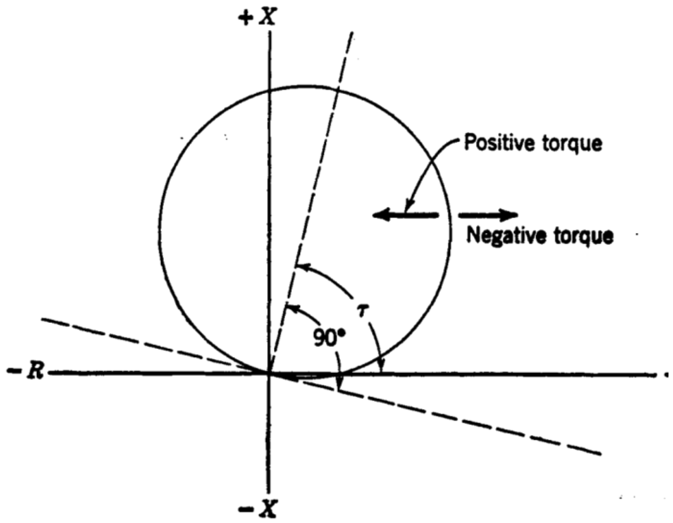
If we neglect the effect of the control spring,

$$X - \frac{K_1}{K_2} - \text{constant}$$

In other words, this relay has an operating characteristic such that all impedance radius vectors whose heads lie on this characteristic have a constant X component. This describes the straight line of Figure. The significant thing about this characteristic is that the resistance component of the impedance has no effect on the operation of the relay; the relay responds solely to the reactance component. Any point below the operating characteristic–whether above or below the R axis–will lie in the positive-torque region



A reactance-type distance relay for transmission-line protection could not use a simple directional unit as in the impedance-type relay, because the reactance relay would trip under normal load conditions at or near unity power factor, as will be seen later when we consider what different system-



operating conditions "look" like on the R-X diagram. The reactance-type distance relay requires a directional unit that is inoperative under normal load conditions.

The type of unit used for this purpose has a voltage-restraining element that opposes a directional element, and it is called an "admittance" or "mho" unit or relay. In other words, this is a voltage-restrained directional relay. When used with a reactance type distance relay, this unit has also been called a "starting unit" .If we let the control-spring effect be - K3, the torque of such a unit is:

$$T - K_1 VI \cos(\theta - \tau) - K_2 V^2 - K_3$$

At the balance point, the net torque is zero, and hence:

$$K_2V^2 - K_1VI\cos(\theta-\tau) - K_3$$

Dividing both sides by K2 VI, we get:

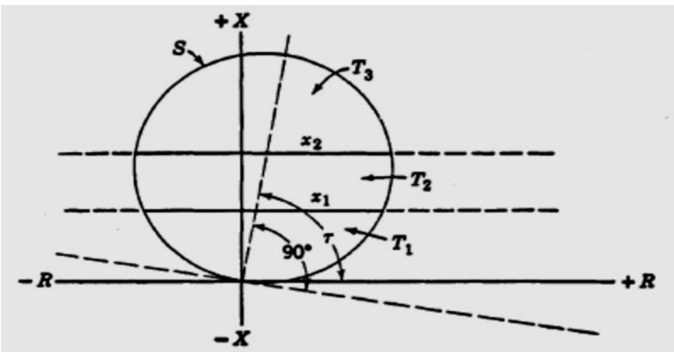
$$\frac{V}{I} - Z - \frac{K_1}{K_2}\cos(\theta-\tau) - \frac{K_3}{K_2VI}$$

If we neglect the control-spring effect,

$$Z - \frac{K_1}{K_2}\cos(\theta-\tau)$$

It will be noted that this equation is like that of the directional relay when the control spring effect is included, but that here there is no voltage term, and hence the relay has but one circular characteristic.

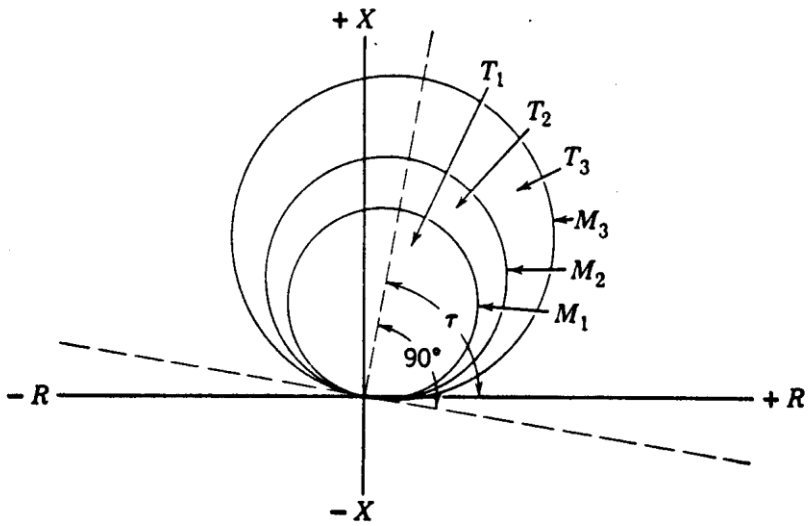
The operating characteristic described by this equation is shown in figure. The diameter of this circle is practically independent of voltage or current, except at very low magnitudes of current or voltage when the control-spring effect is taken into account, which causes the diameter to decrease.



The complete reactance-type distance relay has operating characteristics as shown in these characteristics are obtained by arranging the various units as described in for the impedance-type distance relay. It will be observed here, however, that the directional or starting unit (S) serves double duty, since it not only provides the directional function but also provides the third step of distance measurement with inherent directional discrimination.

THE MHO TYPE DISTANCE RELAY

The complete distance relay for transmission-line protection is composed of three high- speed mho units (M1, M2, and M3) and a timing unit, connected in a manner similar to that shown for an impedance-type distance relay, except that no separate directional unit is required, since the mho units are inherently directional. The operating characteristic of the entire relay is shown on Figure.



The operating-time-versus-impedance characteristic of the mho-type distance relay is the same as that of the impedance-type distance relay.

By means of current biasing similar to that described for the offset impedance relay, a mho- relay characteristic circle can be offset so that either it encircles the origin of the R-X diagram or the origin is outside the circle.

GENERAL CONSIDERATIONS APPLICABLE TO ALL DISTANCE RELAYS

OVERREACH

When a short circuit occurs, the current wave is at offset initially. Under such conditions, distance relays tend to “overreach”, i.e., to operate for a larger value of impedance than that for which they are adjusted to operate under steady-state conditions. This tendency is greater, the more inductive the impedance is. Also, the tendency is greater in electromagnetic-attraction-type relays than in induction-type relays. The tendency to overreach is minimized in the design of the relay-circuit elements, but it is still necessary to compensate for some tendency to overreach in the adjustment of the relays.

Compensation for overreach as well as for inaccuracies in the current and voltage sources is obtained by adjusting the relays to operate at 10% to 20% lower impedance than that for which they would otherwise be adjusted. This will be further discussed when we consider the application of these relays.

MEMORY ACTION

Relays in which voltage is required to develop pickup torque, such as mho-type relays or directional units of other relays, may be provided with “memory action”. Memory action is a feature that can be obtained by design in which the current flow in a voltage-polarizing coil does not cease immediately when the voltage on the high-voltage side of the supply voltage transformer is instantly reduced to zero. Instead, the stored energy in the voltage circuit causes sinusoidal current to flow in the voltage coil for a short time. The frequency of this current and its phase angle are for all practical purposes the same as before the high-tension voltage dropped to zero, and therefore the relay is properly polarized since, in effect, it “remembers” the voltage that had been impressed on it. It will be evident that memory action is usable only with high-speed relays that are capable of operating within the short time that the transient polarizing current flows. It will also be evident that a relay must have voltage applied to it initially for memory action to be effective.

In other words, memory action is ineffective if a distance relay’s voltage is obtained from the line side of a line circuit breaker and the breaker is closed when there is a short circuit on the line. Actually, it is a most rare circumstance when a short circuit reduces the relay supply voltage to zero. The short circuit must be exactly at the high-voltage terminals of the voltage transformer, and there must be no arcing in the short circuit. About the only time that this can happen in practice is when maintenance men have forgotten to remove protective grounding devices before the line breaker is closed. The voltage across an arcing short circuit is seldom less than about 4% of normal voltage, and this is sufficient to assure correct distance-relay operation even without the help of memory action. Memory action does not adversely affect the distance-measuring ability of a distance relay. Such ability is important only for impedance values near the point for which the operating time steps from T1 to T2 or from T2 to T3. For such impedances, the primary voltage at the relay location does not go to zero, and the effect of the transient is “swamped”.

THE VERSATILITY OF DISTANCE RELAYS

It is probably evident from the foregoing that on the R-X diagram we can construct any desired distance-relay operating characteristic composed of straight lines or circles. The characteristics shown here have been those of distance relays for transmission-line protection. But, by using these same characteristics or modifications of them, we can encompass any desired area on the R-X diagram, or we can divide the diagram into various areas, such that relay operation can be obtained only for certain relations between V, I. That this is a most powerful tool will be seen later when we learn what various types of abnormal system conditions "look" like on the R-X diagram.

THE SIGNIFICANCE OF Z

Since we are accustomed to associating impedance with some element such as a coil or a circuit of some sort, one might will ask what the significance is of the impedance expressed by the ratio of the voltage to the current supplied to a distance relay. To answer this question completely at this time would involve getting too far ahead of the story. It depends, among other things, on how the voltage and current supplied to the relay are obtained. For the protection of transmission lines against short circuits, which is the largest field of application of distance relays, this impedance is proportional, within certain limits, to the physical distance from the relay to the short circuit. However, the relay will still be energized by voltage and current under other than short-circuit conditions, such as when a system is carrying normal load, or when one part of a system loses synchronism with another, etc. Under any such condition, the impedance has a different significance from that during a short circuit. This is a most fascinating part of the story, but it must wait until we consider the application of distance relays.

At this point, one may wonder why there are different types of distance relays for Transmission-line protection such as those described. The answer to this question is largely that each type has its particular field of application wherein it is generally more suitable than any other type. This will be discussed when we examine the application of these relays. These fields of application overlap more or less, and, in the overlap areas, which relay is chosen is a matter of personal preference for certain features of one particular type over another.

FEATURES OF DISTANCE RELAY

AUTORECLOSER

In electric power distribution, a recloser, or autorecloser, is a circuit breaker equipped with a mechanism that can automatically close the breaker after it has been opened due to a fault.Reclosers are used on overhead distribution systems to detect and interrupt momentary faults. Since many short-circuits on overhead lines clear themselves, a recloser improves service continuity by automatically restoring power to the line after a momentary fault.

Controls for the reclosers range from the original electromechanical systems to digital electronics with metering and SCADA functions. The ratings of reclosers run from 2.4–38 kV for load currents from 10–1200 A and fault currents from 1–16 kA.

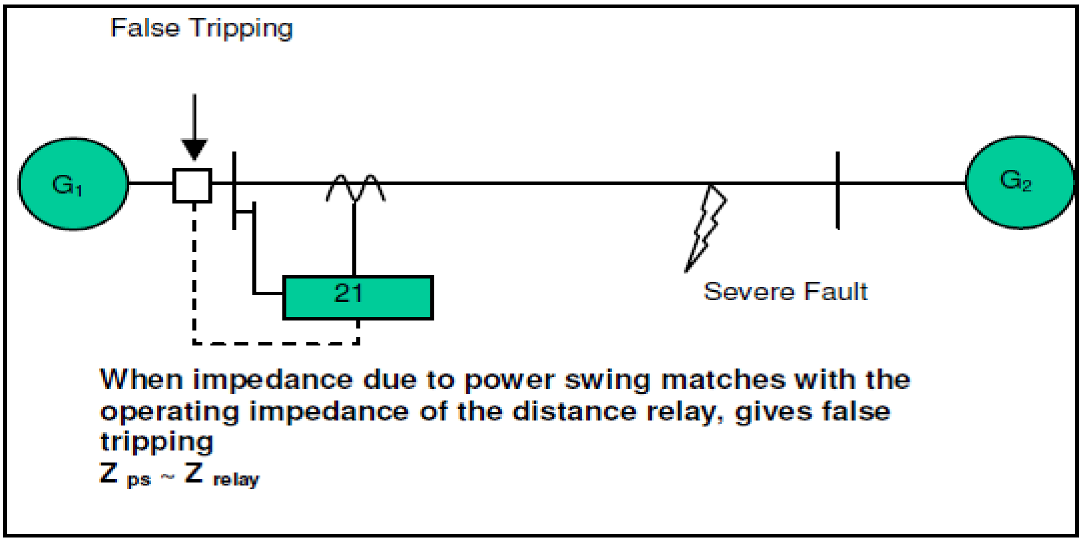
POWER SWING

Power Swing which is basically caused by the large disturbances in the power system which if not blocked could cause wrong operation of the distance relay and can generates wrong or undesired tripping of the transmission line circuit breaker. And if not prevented from the generator could cause severe damage to the machine.

Power Swing Effect on the Distance Relay Power swings can cause the load impedance, which under steady state conditions is not within the relay's operating characteristic, to enter into the relay's operating characteristic.

Operation of these relays during a power swing may cause undesired tripping of transmission lines or other power system elements, thereby weakening the system and possibly leading to cascading outages and the shutdown of major portions of the power system.

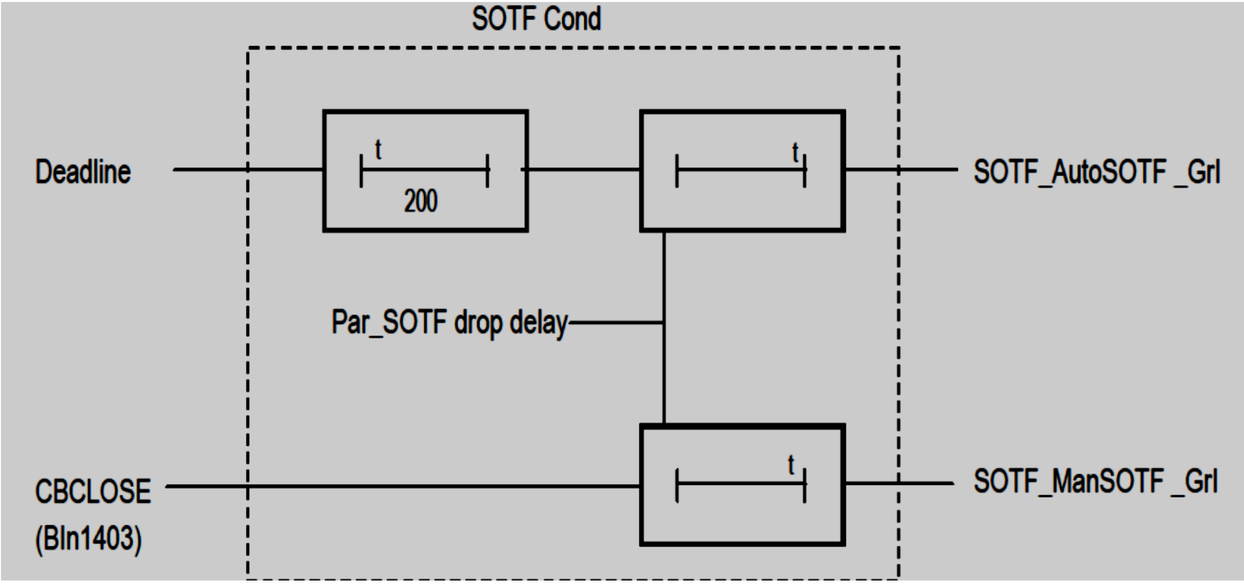
Distance or other relays should not trip during such as stable or unstable power swings, and allow the power system to return to a stable operating condition. Distance relay elements prone to operate during stable or transient power swings should be temporarily inhibited from operating to prevent system separation from occurring at random or in other than pre-selected locations. A Power Swing Block (PSB) function is available in modern relays to prevent unwanted distance relay element operation during power swings. The main purpose of the PSB function is to differentiate between faults and power swings and block distance or other relay elements from operating during a power swing. However, faults that occur during a power swing must be detected and cleared with a high degree of selectivity and dependability.



SWTICH ON TO FAULTS

Some protection functions, e.g. distance protection, directional overcurrent protection, etc. also need to decide the direction of the fault. This decision is based on the angle between the voltage and the current. In case of close-up faults, however, the voltage of the faulty loop is near zero: it is not sufficient for a directional decision. If there are no healthy phases, then the voltage samples stored in the memory are applied to decide if the fault is forward or reverse. If the protected object is energized, the close command for the circuit breaker is received in “dead” condition. This means that the voltage samples stored in the memory have zero values. In this case the decision on the trip command is based on the programming of the protection function for the “switch-onto-fault” condition. This “switch-onto-fault” detection function prepares the conditions for the subsequent decision. The function can handle both automatic and manual close commands. The automatic close command is not an input for this function. It receives the “Dead line” status signal from the DLD (dead line detection) function block. After dead line detection, the AutoSOTF binary output is delayed by a timer with a constant 200 ms time delay. After voltage detection (resetting of the dead line detection input signal), the drop-off of the output signal is delayed through a timer set by the user. The manual close command is an input binary signal. The drop-off of this signal is delayed

by a timer with timing set by the user. The fault detection is the task of the subsequent distance protection, directional overcurrent protection, etc.
The operation of the "switch-onto-fault" detection function is shown in the following figure



TELE PROTECTION

A secure and uninterrupted supply of electricity is only possible with the help of comprehensive protection and control functions, which ensure the reliable operation of the power system. As the complexity and ratings of electrical power systems increase, so do also the demands on the protective devices and systems, which have to protect them from damage and preserve power system stability. Protection relays in conjunction with communication links provide the best possible means of selectively isolating faults on HV lines, transformers, reactors and other important items of electrical plants. To prevent the system from failure and damage, the teleprotectionsystem has to selectively disconnect the faulty part by transferring command signals within the shortest possible time.

Depending on the protection scheme in use, the command signals trip the remote circuit breaker either directly (direct tripping) or are first enabled by the local protection device (permissive tripping). Other protection schemes involve tripping prevention by the local protection device (blocking). A fundamental requirement in all these applications is that command signals are communicated reliably at the highest possible speed. In the event of a fault on the protected unit, the command signals must be received at the remote end in the shortest possible time even if the channel is disturbed by the fault (dependability). On the other hand, interference on the communications channel must never cause unwanted operation of the protection by simulating a tripping signal when there is no fault on the power system (security). The most important features of tele protection equipment are therefore transmission time, dependability and security. From the communications engineering point of view, the bandwidth in tele protection equipment must also be taken into account.

INTRODUCTION TO SIMULINK

Simulink models, simulates, and analyzes dynamic systems. It enables you to pose a question about a system, model the system, and see what happens.
With Simulink, you can easily build models from scratch, or modify existing models to meet your needs. Simulink supports linear and non-linear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multirate — having different parts that are sampled or updated at different rates.
Thousands of engineers around the world use Simulink to model and solve real problems in a variety of industries.

FEATURES OF SIMULINK

Simulink provides a graphical user interface (GUI) for building models as block diagrams, allowing you to draw models as you would with pencil and paper. Simulink also includes a comprehensive block library of sinks, sources, linear and non-linear components, and connectors. If these blocks do not meet your needs, however, you can also create your own blocks. The interactive graphical environment simplifies the modelling process, eliminating the need to formulate differential and difference equations in a language or program.
Models are hierarchical, so you can build models using both top-down and bottom-up approaches. You can view the system at a high level, and then double-click blocks to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact.

SIMPOWER SYSTEM

SimPowerSystems software is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. It uses the Simulink environment, allowing you to build a model using simple click *and* drag procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library.

SimPowerSystems software belongs to the Physical Modeling product family and uses similar block and connection line interface.
SimPowerSystems libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation.

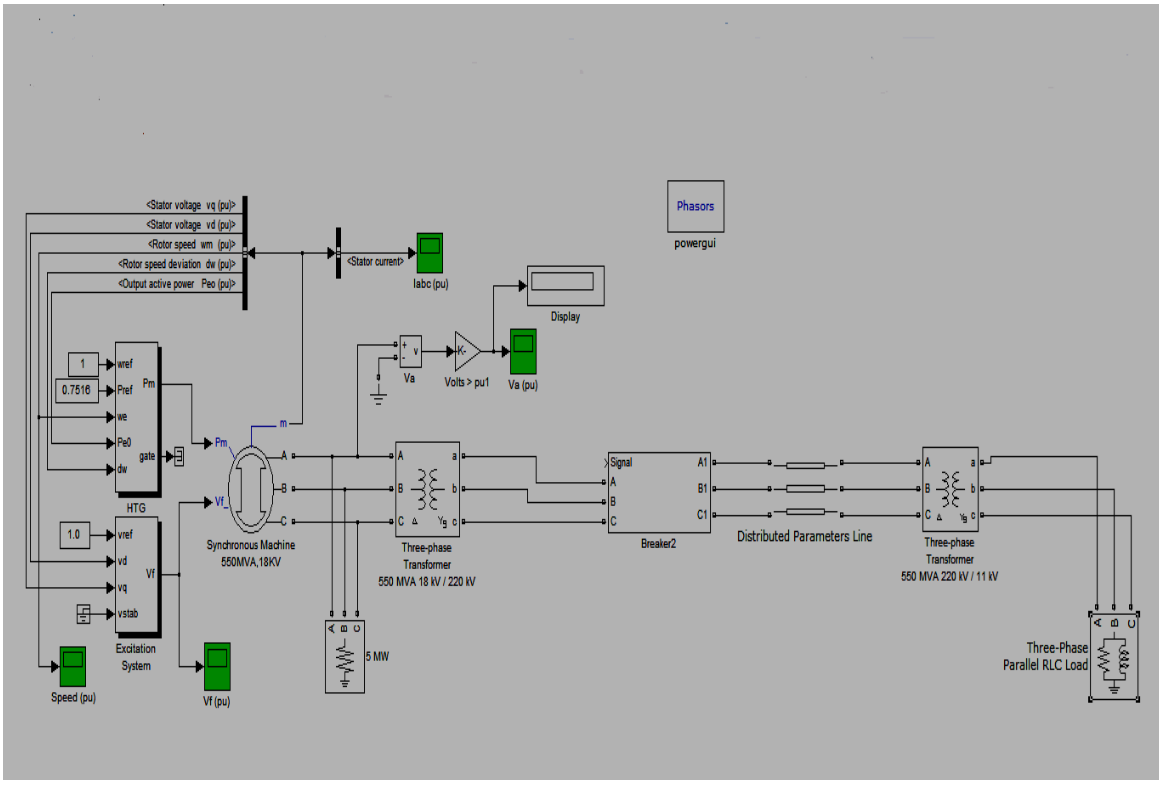
The SimPowerSystems main library, powerlib, organizes its blocks into libraries according to their behavior. The powerlib library window displays the block library icons and names. Double-click a library icon to open the library and access the blocks. The main powerlib library window also contains the Powergui block that opens a graphical user interface for the steady-state analysis of electrical circuits.

BASIC MODEL

Generally our simulation consist of a network of 220 kV line form KDA to PIPRI WEST .In order to energise the line consider a generator of 550 MVA (18 KV) .The voltage is further increased by a step up transformer of the same rating of 550 MVA with the voltage level as 18 KV /220 KV.

The network is further completed by adding a 3 phase circuit breaker which tends to isolate the line during faulty conditions,a transmission line of distributed parameters ,a step down transformer of 550 MVA having voltage rating 220 KV/11 KV.At the end of the transmission line a load is connected with an active and reactive power equals to 800 KW and 100 KVA respectively.

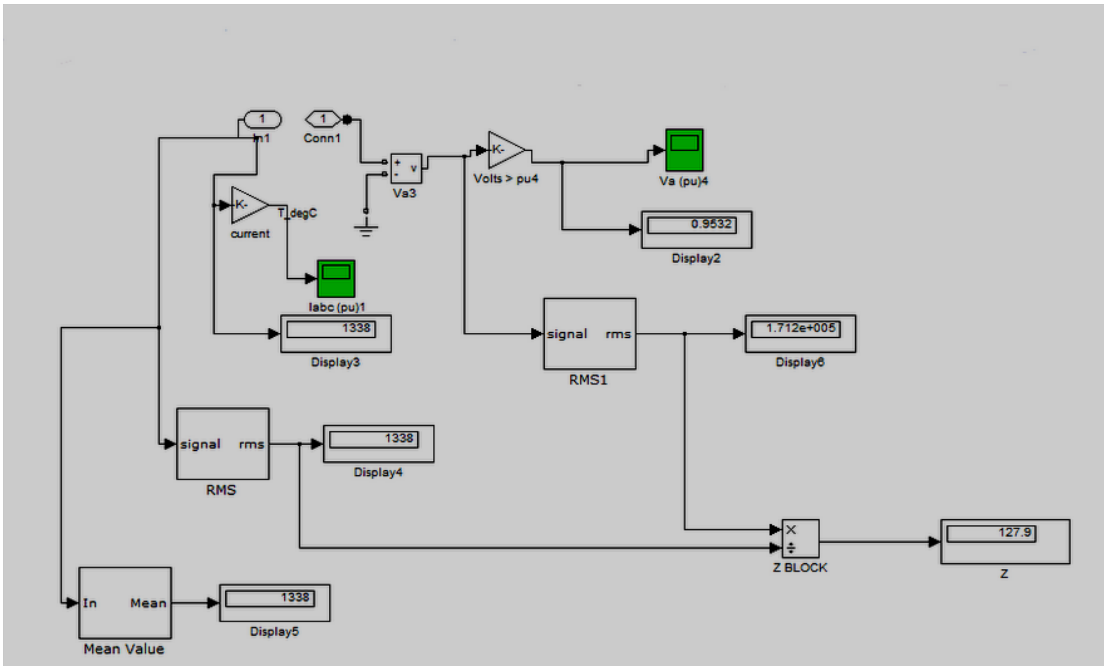
Following is the snapshot of our simulated network.The following network is a radial network for the sake of simplicity.



IMPEDANCE CALCULATION BLOCK

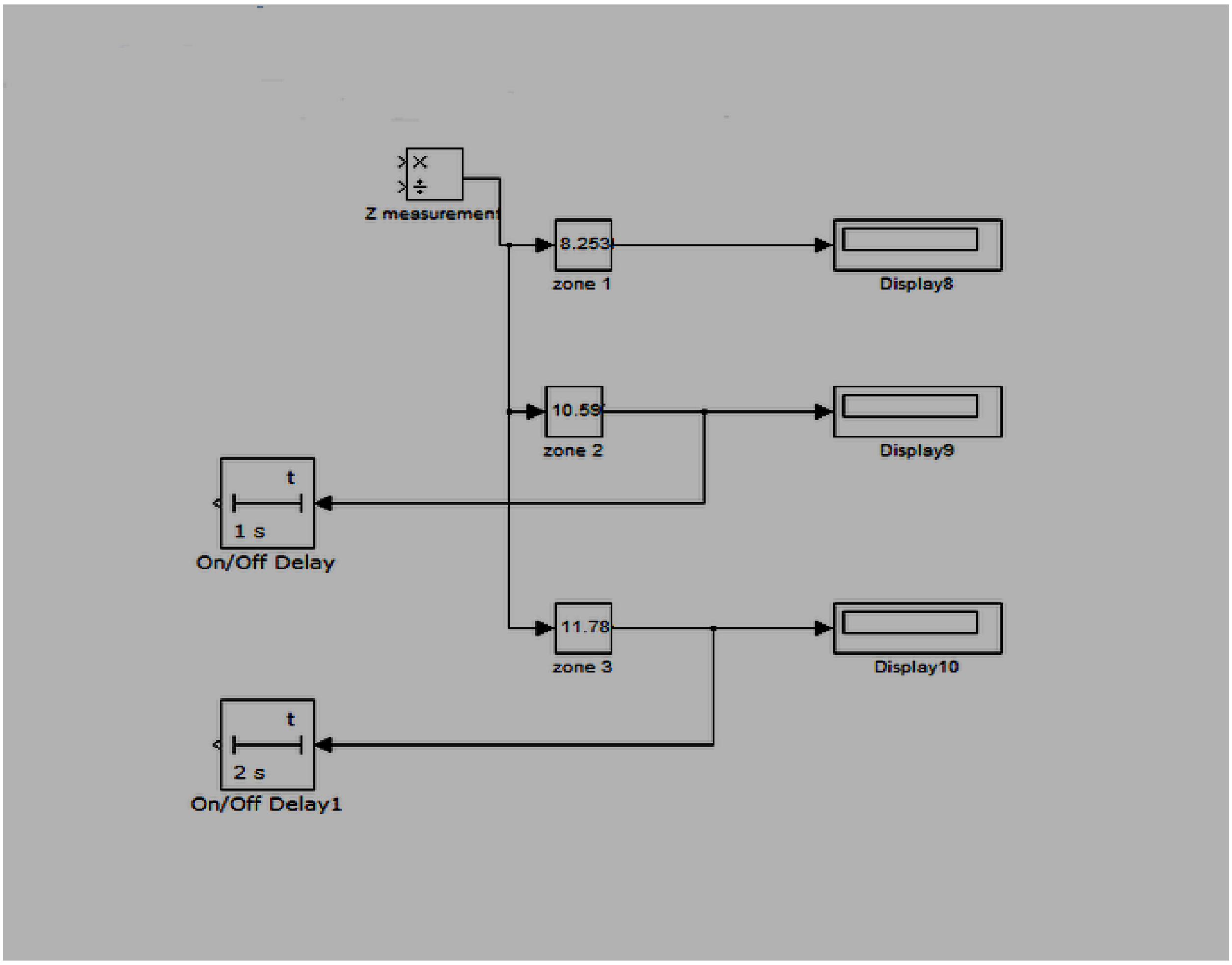
This block constantly measures the RMS values of voltages and currents and calculates the impedance by dividing both the values as

$$\boxed{Z=V/I}$$



TRIPPING CIRCUIT

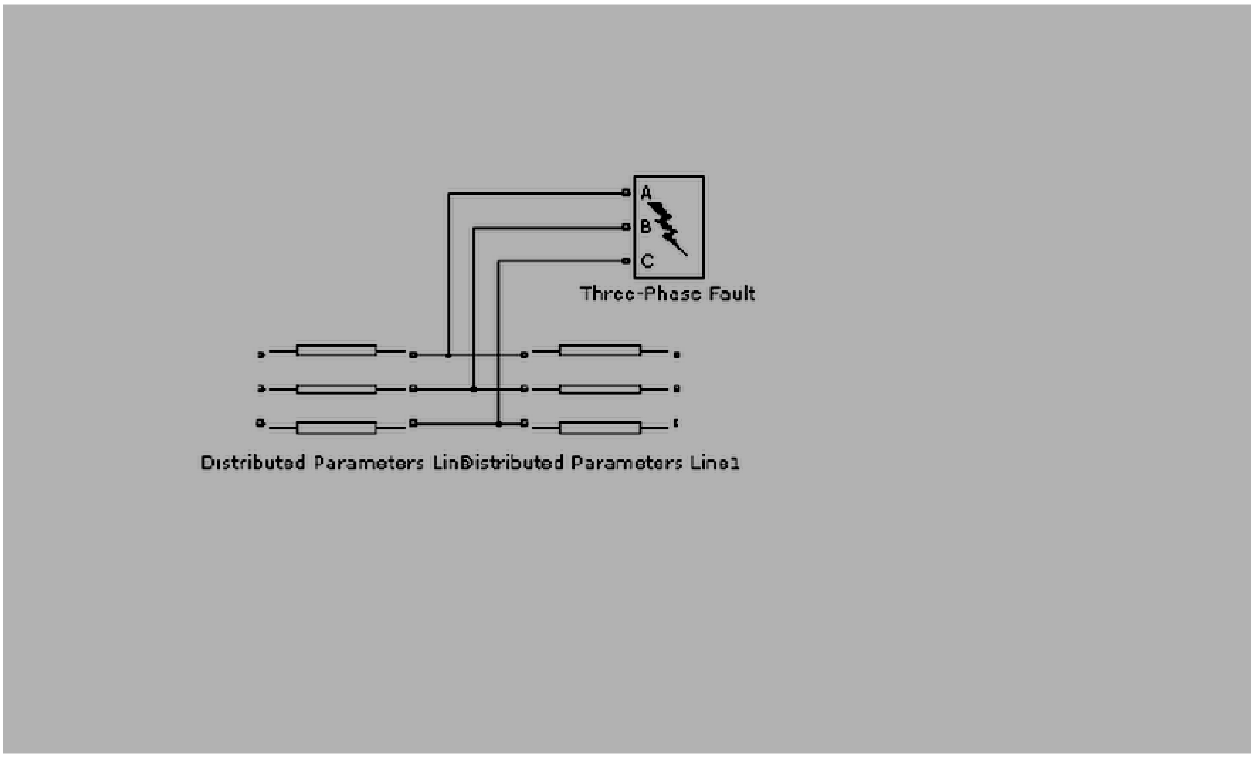
Tripping circuit is also an important part of our simulation.It is basically a relay block which generates signals to the circuit breaker to trip in faulty conditions.It constantly measures the impedances of the zones and decides whether to trip the circuit or not on the basis of value of impedances.Its also consists of delay blocks through which we can set the delay in the operation of relays.



FAULT

Faults in a transmission line can be either phase to phase or phase to ground. In both the conditions heavy current flows from the transmission line and impedance of the line changes.

In our simulation we introduce a fault of any nature by breaking the transmission line into two variable lengths and inserting a fault between them.



RELAY SETTINGS

SETTINGS FOR RELAY 1

- **PROTECTED LINE DATA:**

Length LA	= 33.00 km
Positive sequence resistance R1A	= 0.6765Ω
Positive sequence reactance X1A	= 3.9270Ω
Zero sequence resistance R0A	= 5.2580Ω
Zero sequence reactance X0A	= 32.4390Ω
Rated impedance of the line	=9.72 Ω

- **DATA FOR 1 ST CONSECUTIVE LINE: FROM PIPRI WEST SS TO B.Q.P.S:**

Length LB	= 6.00 km
Positive sequence resistance R1B	= 0.1350Ω
Positive sequence reactance X1B	= 1.9170Ω
Zero sequence resistance R0B	= 2.0520Ω
Zero sequence reactance X0B	= 8.5680Ω
Rated impedance	=1.715 Ω

- **DATA FOR 2ND CONSECUTIVE LINE : FROM PIPRI WEST TO ICI SS:**

Length LC	= 8.200 km
Positive sequence resistance R1C	= 0.2124Ω.
Positive sequence reactance X1C	= 2.5363Ω
Zero sequence resistance R0C	= 2.5092Ω
Zero sequence reactance X0C	= 4.9495Ω
Rated impedance	=2.465 Ω

INSTRUMENT TRANSFORMERS

- Current Transformer

Primary rating	=2500 A
Secondary rating	=1 A

- Voltage Transformer

Primary rating	=220 KV
Secondary rating	=1 V

CALCULATIONS:

Minimum Load Impedance = minimum voltage / (v3 x Maximum load current)

Minimum voltage = 0.85 x Rated voltage =187 KV

Maximum load current =2500 A

Minimum Load Impedance (Zpmin) =43.91 Ω

Zone 1= 85 % of protected line impedance

Reactance (reach) 85% of X1A = =3.380 Ω

Rated impedance (85% of protected line) =8.2535Ω

Time setting =0.00 sec

Zone Direction forward

Zone 2 = Protected line + 50 % of first consecutive line

Reactance (reach) {X1A + 0.5X1B} =

4.8855Ω

Impedance reach {Z1+50% of 1st consecutive line} =10.597Ω

Time setting =1.00 sec

Zone Direction Forward

Zone 3 = Protected line + 115 % of first consecutive line

Reactance (reach) {X1A + 115%X1B} =6.1316Ω

Rated impedance {Z1+115% of 1st consecutive line} =11.784

Time setting =2.0 sec

Zone Direction forward

Zone 4 = Inactive

Zone 5 = Inactive

Switch on to fault (SOTF)

Function switch on to fault	=<u>ON</u>
Setting of SOTF over current	I>>> = <u>2.5</u>A

Power swing detection

Block tripping of all zones on recognition of a power swing

SETTINGS FOR RELAY 2 (at line 1)

- **PROTECTED LINE DATA:**

Length	= <u>33.00</u> km
Positive sequence resistance R1A	= <u>0.6765</u> Ω
Positive sequence reactance X1A	= <u>3.9270</u> Ω
Zero sequence resistance R0A	= <u>5.2580</u> Ω
Zero sequence reactance X0A	= <u>32.439</u> Ω
Rated impedance of the line	=<u>9.7200</u> Ω

Zone 1= 15 % of protected line impedance

Reactance (reach) 15% of X1A	=<u>0.5890</u>Ω
Rated impedance (15% of protected line)	=<u>1.45</u> Ω
Time setting	=<u>0.00</u> sec
Zone Direction	backward

FAULT ANALYSIS FOR RELAY 1

Consider four faults ,three of which occurring in tripping zone of relay 1 and one occurring outside the tripping zone of relay 1 with the following distances.

1. At distance of 20 Km of protected line.
2. At distance of 2 Km of 1^{st} consecutive line.
3. At distance of .5 Km of 2^{nd} consecutive line.
4. At distance of 5 Km of 2^{nd} consecutive line.

➢ FAULT 1:

Fault occurs at a distance of 20 Km of protected line.

FAULT TIMINGS:

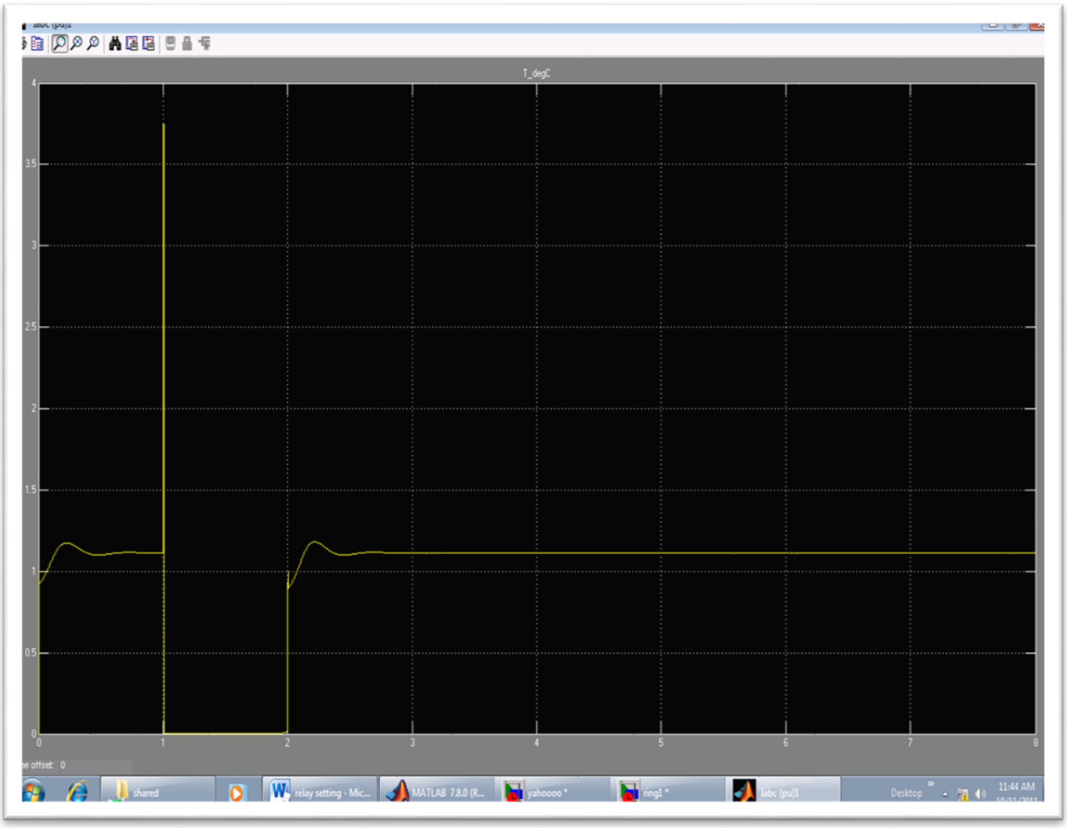
Fault occurs T=<u>1.00</u> sec

Fault clearance T=<u>2.00</u>sec

EXPECTED OPERATION:

The breaker will instantaneously open at T=1.00 sec and as the fault clears at T=2.00 sec, the breaker will reclosed.

SIMULATED RESULT:



➢ FAULT 2:

Fault occurs at a distance of 2 Km of 1st consecutive line.

FAULT TIMINGS:

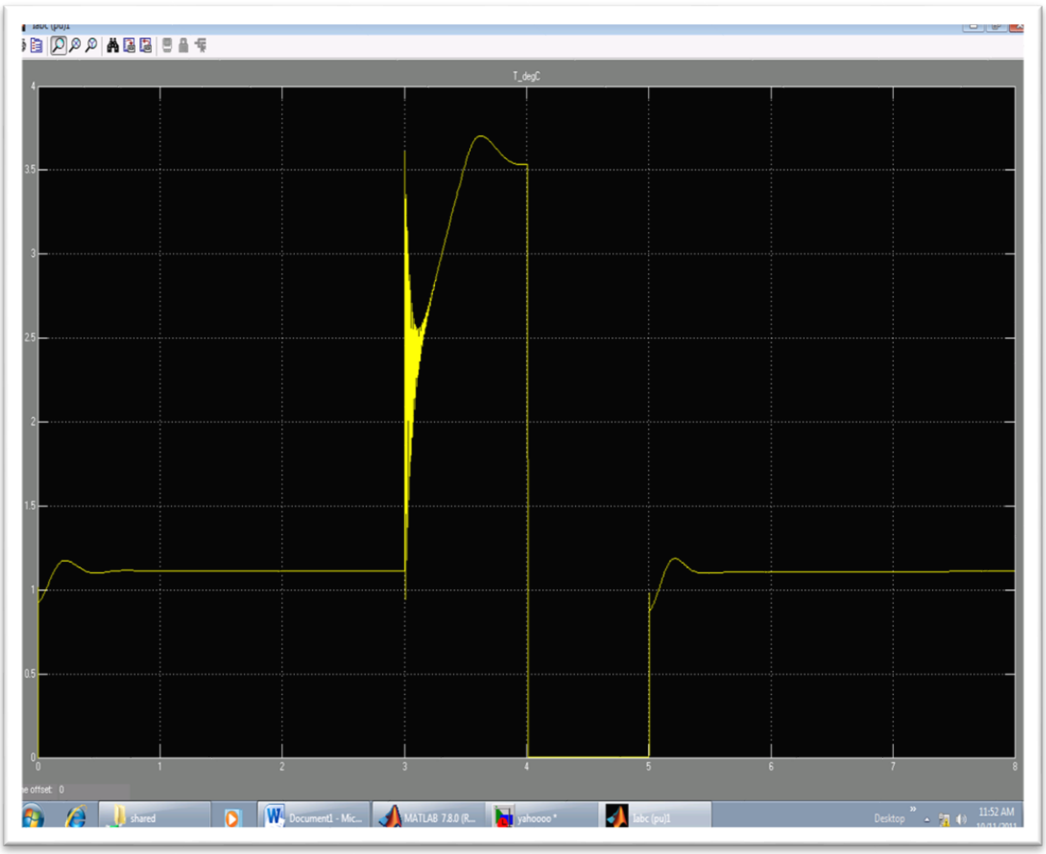
Fault occurs T=3.00 sec

Fault clearance T=5.00sec

EXPECTED OPERATION:

The breaker will open at T=4.00 sec as there is a delay of 1.00 sec in our relay setting ,there will be an enormous flow of current during 4th second and the fault clears at T=5.00 sec, the breaker will reclosed.

SIMULATED RESULT:



➢ FAULT 3:

Fault occurs at a distance of 0.5 Km of 2nd consecutive line.

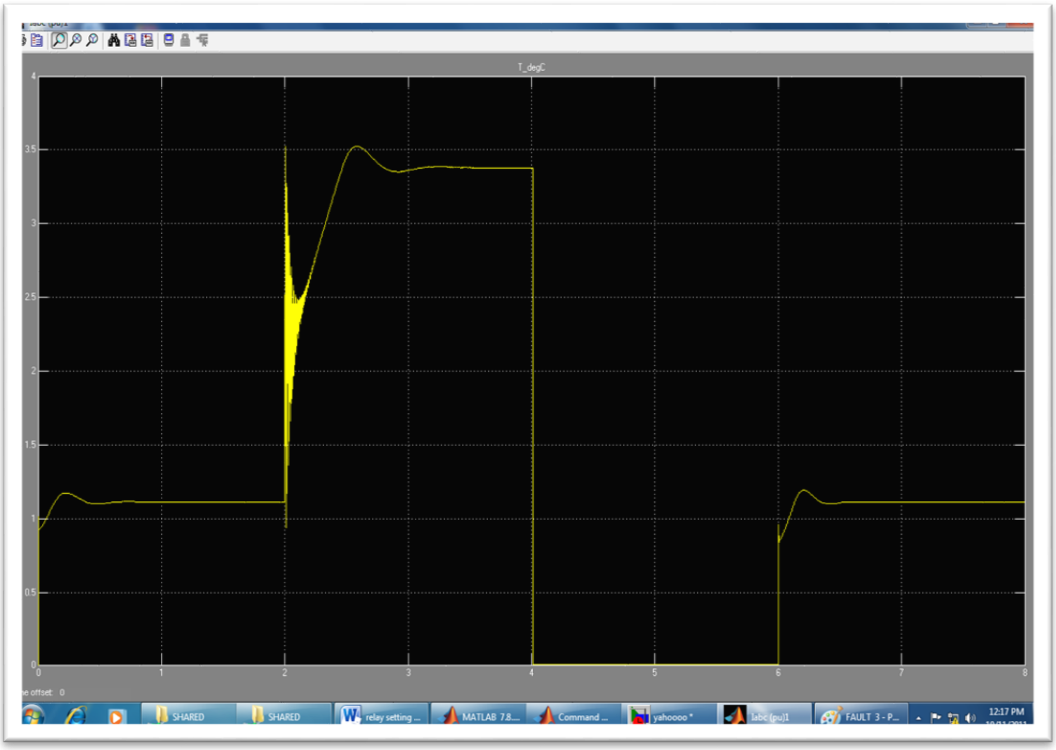
FAULT TIMINGS:

Fault occurs	T=2.00 sec
Fault clearance	T=6.00 sec

EXPECTED OPERATION:

The breaker will open at T=4.00 sec as there is a delay of 2.00 sec in our relay setting ,there will be an enormous flow of current during 3rd and 4th second and during 5th and 6th second there will be no flow of current as the breakeris opened. The fault clears at T=6.00 sec, the breaker will reclosed.

SIMULATED RESULT:



➢ FAULT 4:

Fault occurs at a distance of 5 Km of 2nd consecutive line.

FAULT TIMINGS:

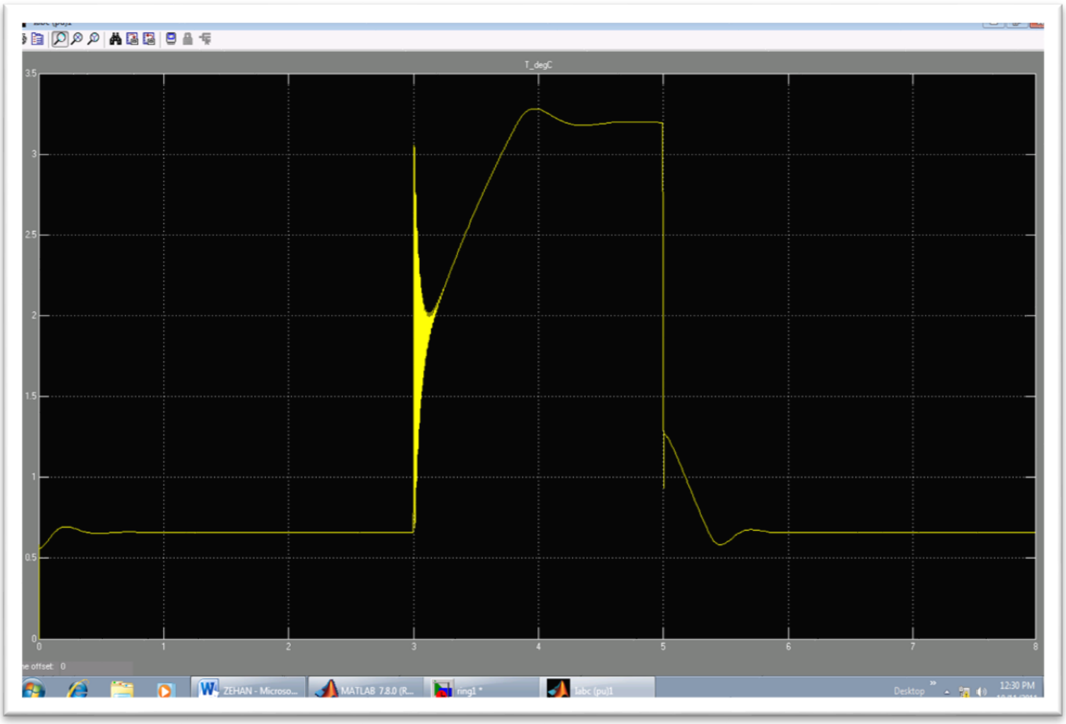
Fault occurs T=3.00 sec

Fault clearance T=5.00 sec

RELAY 1 REMAINS INACTIVE

As the fault is out of the region for relay 1 so it will remain inactive. So a large amount of current will flow during this faulty condition. But in actual practice, the relay placed at the terminating end of the 2nd consecutive line will operate and removes the faulty portion.

SIMULATED RESULTS:



FAULT ANALYSIS FOR RELAY 2

- **FAULT OCCURRING BETWEEN 85 % TO 100% OF PROTECTED LINE**

According to the settings of relay 1, the fault after 85% to 100% of protected line will trip after a delay of 1.00 sec but we need to remove the fault as it is occurring in the premises of primary protected region so relay 2 present at the terminating end of protected line will generates the signal to the circuit breaker to isolate the line instantaneously.
Fault occurs at a distance of 30 Km of protected line.

FAULT TIMINGS:

Fault occurs	T=1.00 sec
Fault clearance	T=3.00 sec

EXPECTED OPERATION:

The breaker will instantaneously open at T=1.00 sec and as the fault clears at T=3.00 sec, the breaker will reclosed.

SIMULATED RESULT: