PROJECT REPORT

ON

"SIMULATION OF RELAY IN REAL TIME SYSTEM"

A Report submitted in partial fulfilment of the requirements for the Award of Degree of

BACHELOR OF TECHNOLOGY

in Electrical Engineering

SUBMITTED BY:

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UNDER THE SUPERVISION **OF**

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CERTIFICATE

We, hereby certify that the report submitted by AMAN KUMAR (2K20/EE/30) ANKUSH KUMAR SAGAR (2K20/EE/40) ANUJ KUMAR JHA (2K20/EE/49), on the topic of Induction Motor Controller and Protection system to Department of Electrical engineering , Delhi Technological University ,DELHI , as part of project work is a record of work carried out by the students under my supervision. To the best of my knowledge ,this workhas not been submitted in part of full for any other company or elsewhere.

- Place:DTU, Delhi Date-
- PROF. S.T. NAGARAJAN

DECLARATION

We hereby certify that the work which is being presented at “Delhi Technological University” by AMAN KUMAR (2K20/EE/30) ANKUSH KUMAR SAGAR (2K20/EE/40) ANUJ KUMAR JHA (2K20/EE/49), in partial fulfilment of requirements for the award of degree of B.Tech. (Electrical Engineering) Submitted in the Department of Electrical Engineering at DELHI TECHNOLOGICAL UNIVERSITY,DELHI is an authentic record of work carried out during a period from November’23 to December’23 under the supervision of PROF. S.T. NAGARAJAN. The matter presented in this project has not been submitted in any other University / Institute for the award of B.Tech. Degree. This is to certify that the above statement made by the student is correct to thebest of our knowledge and belief.

Date: ________________

This is to certify that the above statement made by the student is correct to the best ofour knowledge and belief.

Signatures of Supervisors

Head of Department(Signature)

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Chapter – 1

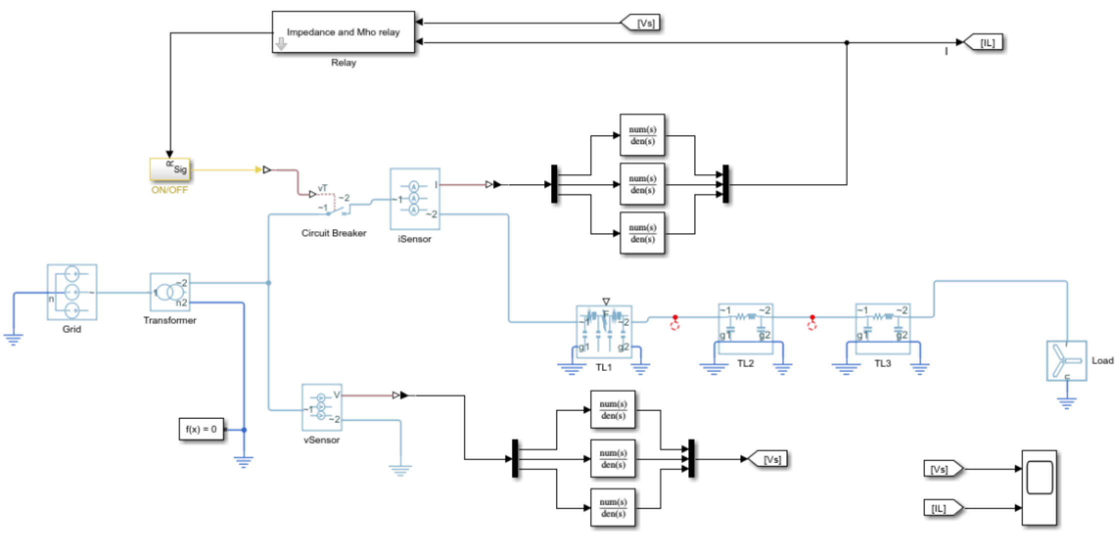
Introduction

1.1 Introduction:

In the intricate tapestry of power systems, the strategic design and seamless integration of a distance relay constitute pivotal steps toward fortifying the reliability and security of electricity transmission. This simulation project embarks on an exhaustive exploration, focusing intently on the intricate nuances of a meticulously crafted distance relay. This relay has been not only conceptualized but also implemented within the power grid, placing a particular emphasis on scrutinizing its performance under an array of fault conditions.

1.2 Objective:

At the heart of this project lies the primary objective: a thorough evaluation of the efficacy and robustness of the bespoke distance relay. Through an exhaustive series of simulations, we aim to subject the relay to a spectrum of fault scenarios, each designed to test and analyze its responsiveness. The goal is not just to detect faults but to unravel the relay's capacity to mitigate



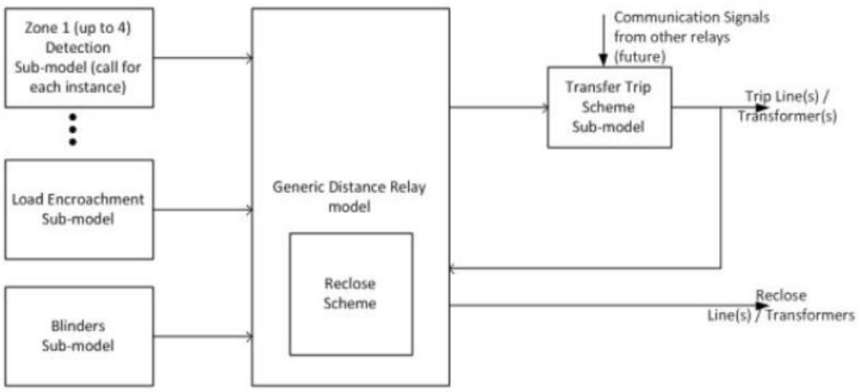
them accurately. By doing so, we aspire to contribute nuanced insights to the ever-evolving field of relay technology.

1.3 Methodology:

The implementation phase intricately weaves the designed distance relay into the fabric of the power grid. This involves strategic placement at key locations, creating a network that mirrors real-world conditions. The subsequent simulation unfolds through a meticulously planned and executed methodology, exposing the relay to diverse fault scenarios. This systematic approach allows for the observation and analysis of the relay's performance under conditions that mimic the dynamic nature of the actual power grid.

1.4 Significance:

The significance of this project extends beyond the conceptualization and simulation of a distance relay; it lies in the practical application of this technology within the power grid. By scrutinizing the relay's performance under a spectrum of fault conditions, our endeavor is not only to contribute to the advancement of relay technology but also to address specific challenges within power systems. The overarching goal is to enhance the grid's resilience by leveraging the precision and adaptability of the implemented distance relay.



Chapter-2
Transmission line

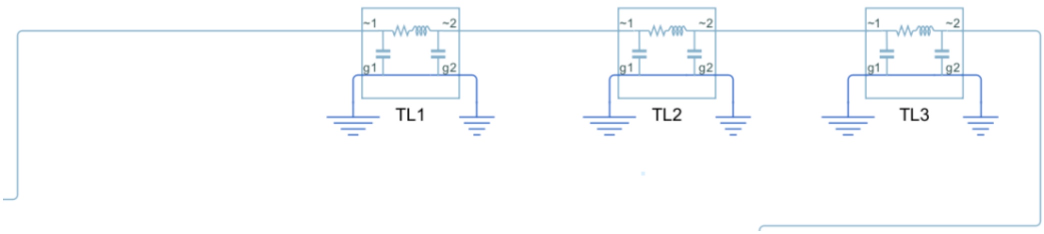
2.1 Introduction

Within the realm of power systems simulation, transmission lines emerge as dynamic entities, wielding a profound impact on the performance of critical components such as distance relays. These conduits of electrical power navigate the grid, serving as essential channels that bridge the gap between generation sources and end-users. In the context of our exploration into the simulation of distance relays, understanding the nuanced interplay between transmission lines and relay behavior becomes paramount.

Transmission lines, characterized by their towering structures or concealed underground cables, constitute the lifelines of our power infrastructure. As we embark on this journey into the intricacies of distance relay simulation, we delve into the fundamental nature of transmission lines as not just carriers of electrical energy, but as influential factors that shape the responsiveness and efficacy of distance relays.

The significance of transmission lines extends beyond their physical presence; they act as dynamic elements that influence fault characteristics, relay settings, and the overall stability of the power grid. In the pursuit of a comprehensive understanding of distance relays, our exploration encompasses the engineering intricacies of these high-voltage conduits, acknowledging their role in creating realistic simulation scenarios that mimic the challenges of real-world power transmission.

Voltage levels, ranging from the elevated to ultrahigh, underscore the unique nature of transmission lines and their impact on the behavior of distance relays. As we navigate through this exploration, we unravel not only the engineering nuances of transmission lines but also their direct implications on the fault detection thresholds and relay settings that define the operational parameters of distance relays.



Overhead lines, stretching across the horizon, and underground cables, navigating the complexities of urban landscapes, provide the backdrop against which distance relays are tested and refined in simulation scenarios. The silent interplay between these conduits and relay responses forms the crux of our investigation, as we seek to optimize relay performance and enhance the reliability of fault detection in the face of diverse transmission line dynamics.

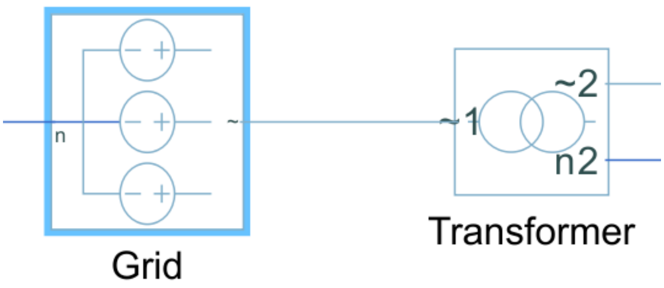
In the subsequent pages, we embark on a comprehensive exploration, dissecting the symbiotic relationship between transmission lines and distance relays. Through simulation studies and theoretical analyses, we aim to unravel the intricacies that define this relationship, shedding light on how the characteristics of transmission lines become pivotal factors in shaping the efficacy of distance relay systems.

2.2 Components of Transmission line

In the intricate network of electrical power systems, a transmission line comprises essential components harmonizing to ensure seamless energy transfer. Voltage sources initiate the power journey, while transmission line conductors act as conduits for electrical flow. Grounding systems ensure safety, dissipating fault currents, and protection equipment, such as relays, orchestrates control, safeguarding the integrity of the transmission line**.**

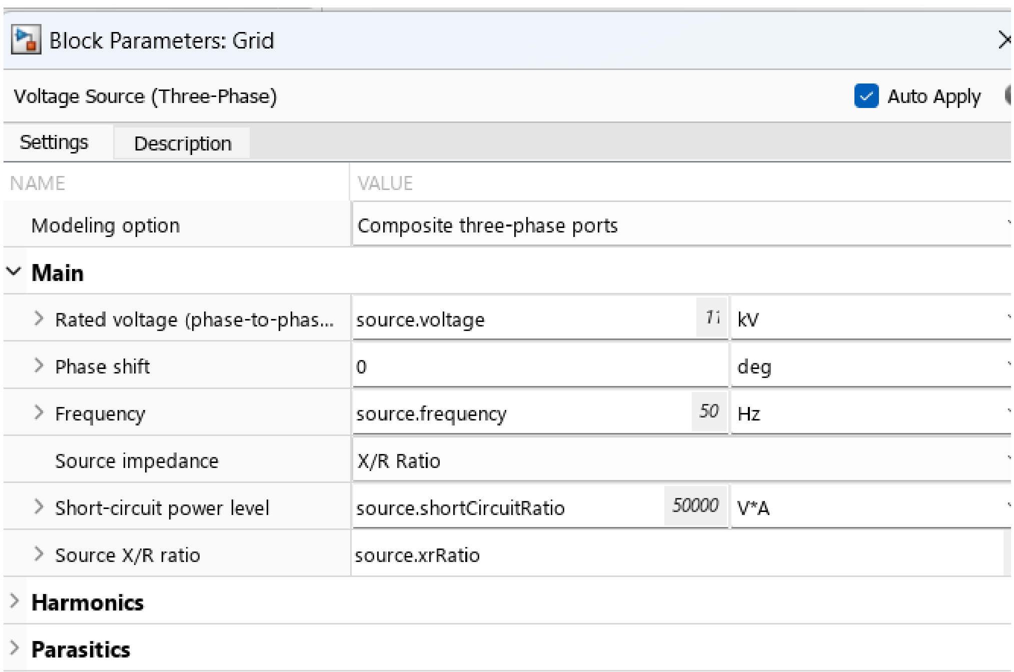
2.2.1 Power source

For the purpose of power supply, a grid and a transformer is used here. Grid is a voltage source block. The AC three-phase voltage source maintains ideal fundamental sinusoidal voltages or fundamental plus harmonic voltages across its output terminals, and can include the effects of source impedance. In the ideal case, the output voltage is defined by

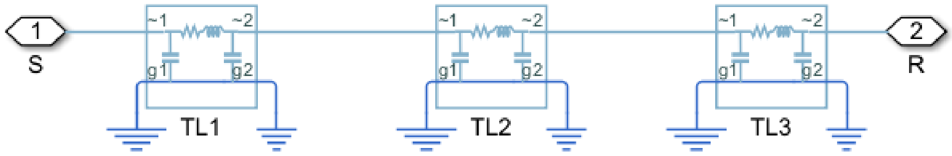


Va = VLINE_RMS * (sqrt(2)/sqrt(3)) * sin(2*pi*FREQ*t + SHIFT)

where VLINE_RMS is the line (i.e. phase-to-phase) RMS voltage, FREQ is the frequency, and SHIFT is the phase shift. Its specifications and values used are given in fig.



2.2.2 Wire Models



Here we have used nominal π method for simulation. The nominal pi model is used in transmission line analysis for its simplicity and accuracy in representing the behaviour of medium to long transmission lines. It offers a balance between computational efficiency and accuracy, making it a practical choice for system studies. The model considers distributed capacitance and inductance, enabling the analysis of wave propagation, voltage, and current distribution along the line without the complexity of a detailed distributed parameter model. This simplification facilitates efficient power flow and transient stability studies in power system analysis.

Parameters are given below as well as faults.

Enable fault	Yes	
Fault type	Single-phase to ground (a-g)	
Faulted phase-neutral resistance	0.02	Ohm
Faulted neutral-ground resistance	0.02	Ohm
Unfaulted phase-neutral conductance	1e-6	1/Ohm
Fault position	0.1	km
Number of segments before fault	1	
Number of segments after fault	1	
Accessible ground connections at fault po...	No	

Fault parameters

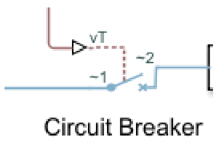
NAME	VALUE		
Modeling option	Composite three-phase ports		
Main			
Line length	cable.length	0.32	km
Frequency used for rlcg specification	60		Hz
Resistance	cable.resistance	0.262	Ohm/km
Inductance	cable.inductance	0.2451	mH/km
Mutual inductance	0		mH/km
Line-line capacitance	cable.capacitanceLL	0.26	uF/km
Line-ground capacitance	cable.capacitanceLG	0.05	uF/km
Mutual resistance	0		Ohm/km

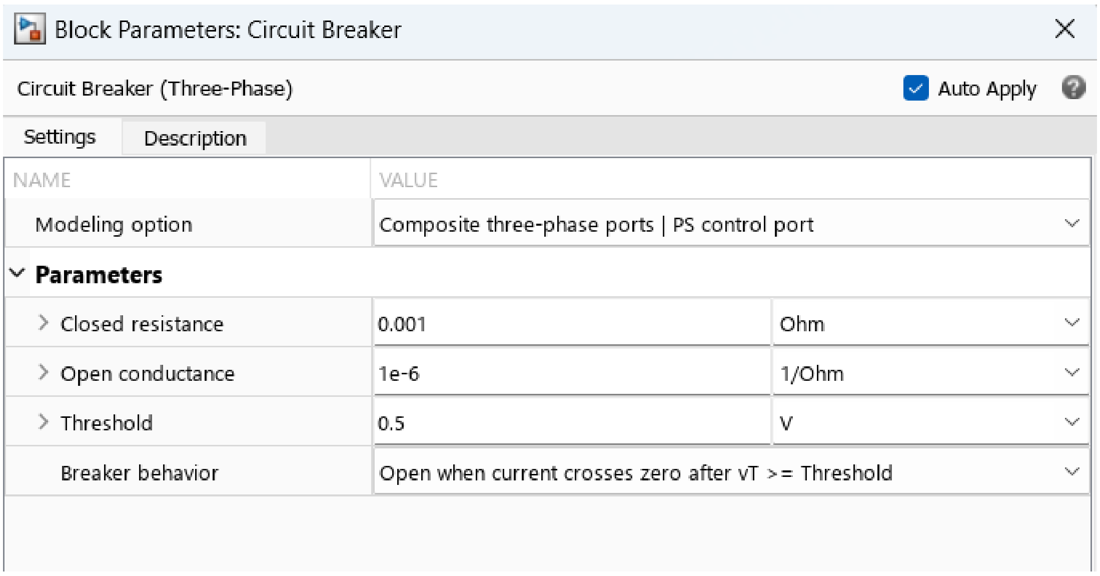
cable.capacitanceLL | ul

Parameters

2.2.3 Circuit Breaker

The block represents three-phase circuit breaker controlled by an external control signal vT. The breaker is closed if voltage vT is less than the threshold. If vT rises above the threshold value, each phase is disconnected in turn as its current crosses zero. It is used to protect ckt from fire and etc.

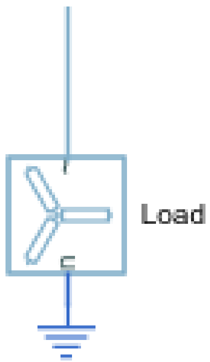


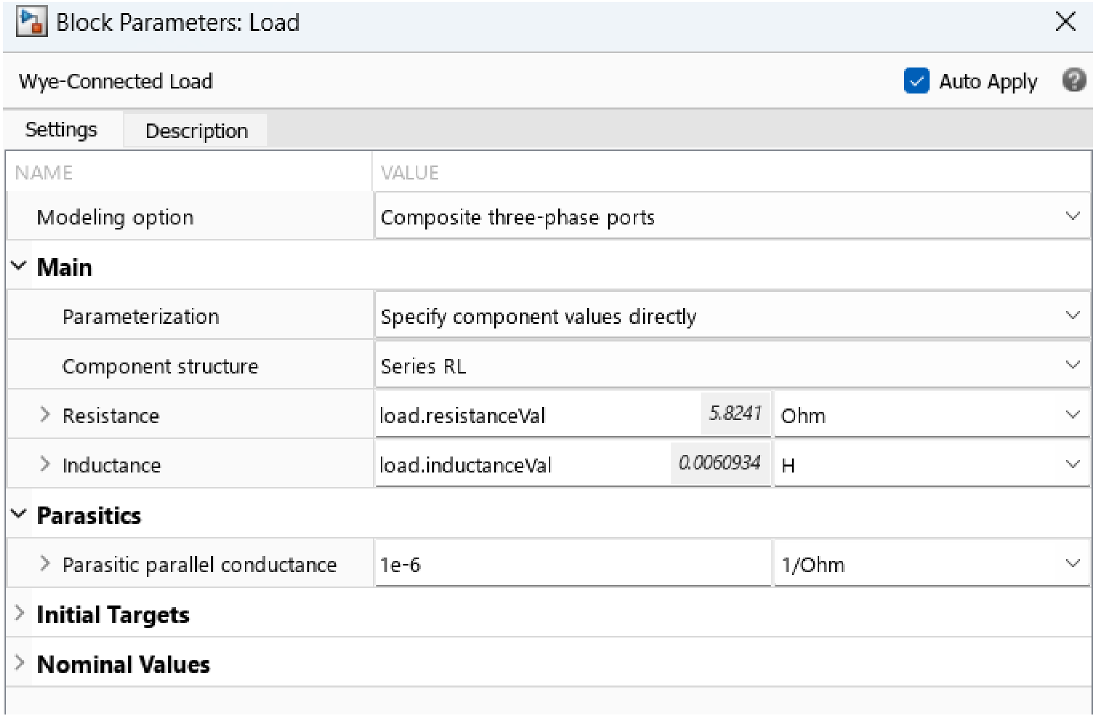


2.2.4 Load

Here we have used a wye-connected load. The impedance of each phase can be represented as either a series or a parallel combination of a resistor, capacitor and inductor. This load is necessary to give realistic touch to simulation.

Load parameters are given below in fig.





Block Parameters: Load
Wye-Connected Load
Auto Apply
Settings
Description
NAME
VALUE
Modeling option
Composite three-phase ports
Main
Parameterization
Specify component values directly
Component structure
Series RL
Resistance
load.resistanceVal
5.8241
Ohm
Inductance
load.inductanceVal
0.0060934
H
Parasitics
Parasitic parallel conductance
1e-6
1/Ohm
Initial Targets
Nominal Values

CHAPTER 3

THE RELAY BLOCK

3.1 What is a Relay?

A protective relay is a device designed to detect abnormal conditions in an electrical power system and initiate appropriate actions to prevent or minimize damage to equipment and maintain the system's stability. The primary function of protective relays is to monitor the electrical parameters of a power system and respond to faults or abnormal conditions by isolating the faulty section, thus preventing further damage.

Common types of protective relays include:

1. Overcurrent relays
2. Overvoltage relays
3. Undervoltage relays
4. Differential relays
5. Distance relays

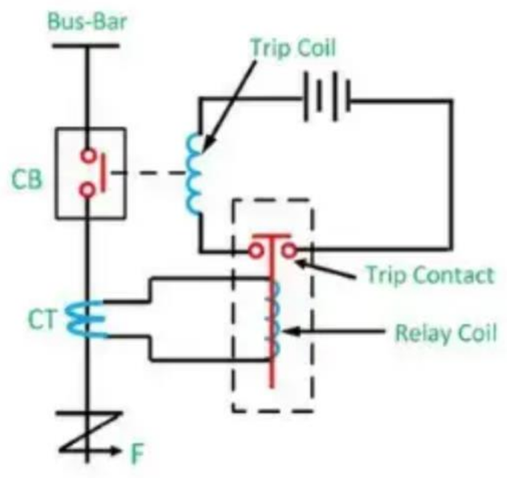


Fig-1: Basics diagram of a protective relay

3.2 Impedance Relay

Impedance relays are crucial components in modern power systems, providing effective protection and fault detection for transmission lines, transformers, and other electrical equipment. They are designed to sense and analyze the relationship between voltage and current, known as impedance, in order to identify and isolate faults quickly and accurately.

Impedance is a complex quantity, expressed in ohms, that represents the opposition a circuit presents to the flow of alternating current (AC). In an electrical power system, the impedance is defined as the ratio of voltage to current, and it is crucial for determining the stability and efficiency of the system. Impedance relays are designed to monitor this impedance and detect when it falls outside of normal operating parameters.

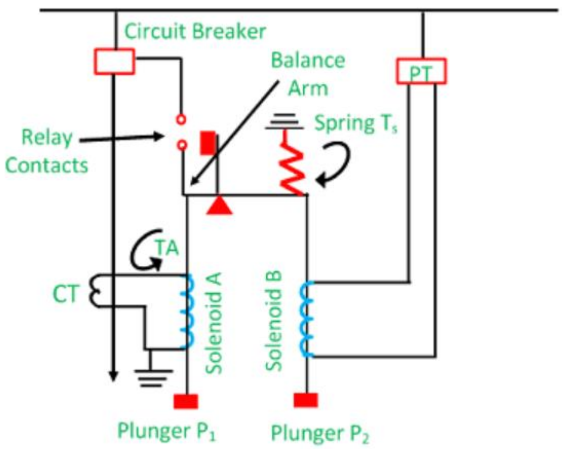


Fig-2: Electromagnetic type impedance relay

An impedance relay consists of several key components, including a voltage transformer, a current transformer, and a sensing unit. The voltage transformer measures the voltage across the protected equipment, while the current transformer measures the current flowing through it. The sensing unit then calculates the impedance based on these measurements and compares it against predefined thresholds. If the impedance exceeds these thresholds, the relay will trip, sending a signal to the circuit breaker to isolate the faulted section of the system.

3.3 Relay Block

This is the relays block that we have used in our simulation. This relay is an impedance and mho relay (depending upon the type of relay we want to use) and it contains 2 inputs as the current and voltage which is sensed through current and voltage sensors respectively, and 1 output which gives trip signal to the circuit breaker to open up its contacts.

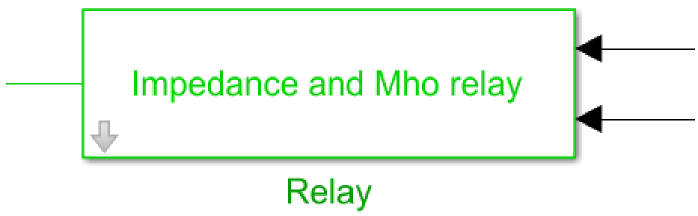


Fig-3 Relay block

The Mho type relay doesn't contain its operating region in the negative part of the y plain or it operates in only in the locus of all points passing through the origin and lies in positive part of R-X plain.

The Impedance relay, on the other hand, doesn't have such restrictions and thus spreads out even in the negative half of X plain.

The Unmasked relay block has been shown below, that we have used in our simulation.

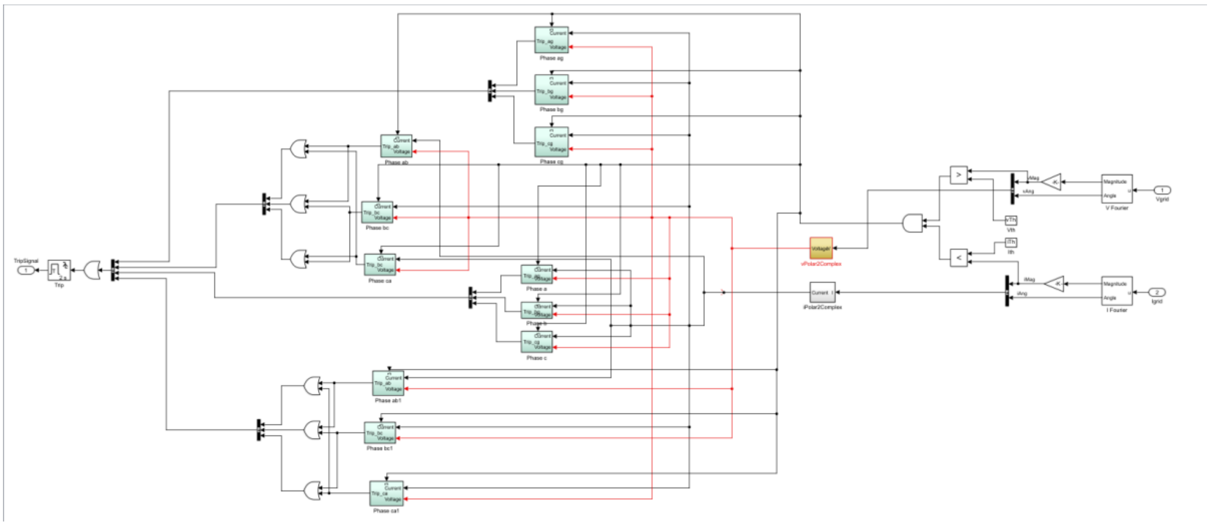


Fig-4: Unmasked diagram of relay block

The red line shown in the above figure is representing the voltage wire, and the black one is for current this notation has been used to distinguish between both the wires.

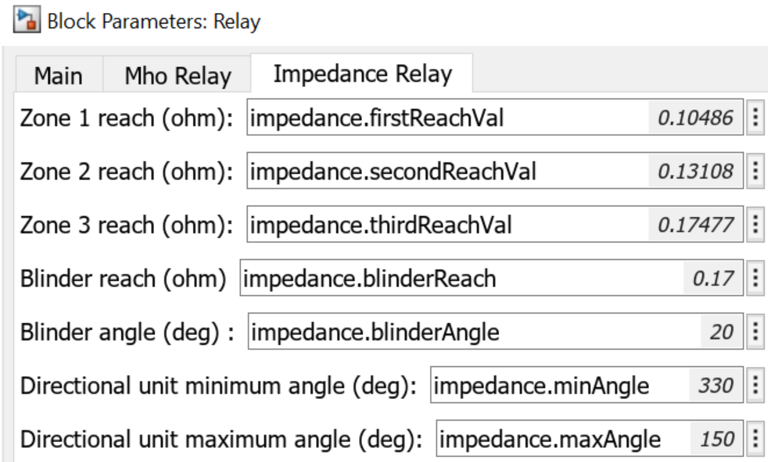


Fig-5: Parameters of relay block

3.3.1 *Blinder block*

Blinder block in our model is responsible for the protection of the relay from the load encroachment under fault condition. If a relay has load encroachment, it means that its settings are too sensitive to changes in load conditions, and it may incorrectly interpret a heavy load as a fault, leading to unnecessary tripping and disruption of power supply.

Blinder block sets up the trip signal after the calculation of impedance from the Z-estimator block.

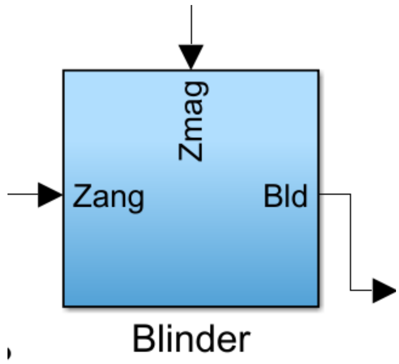


Fig-6: Blinder block

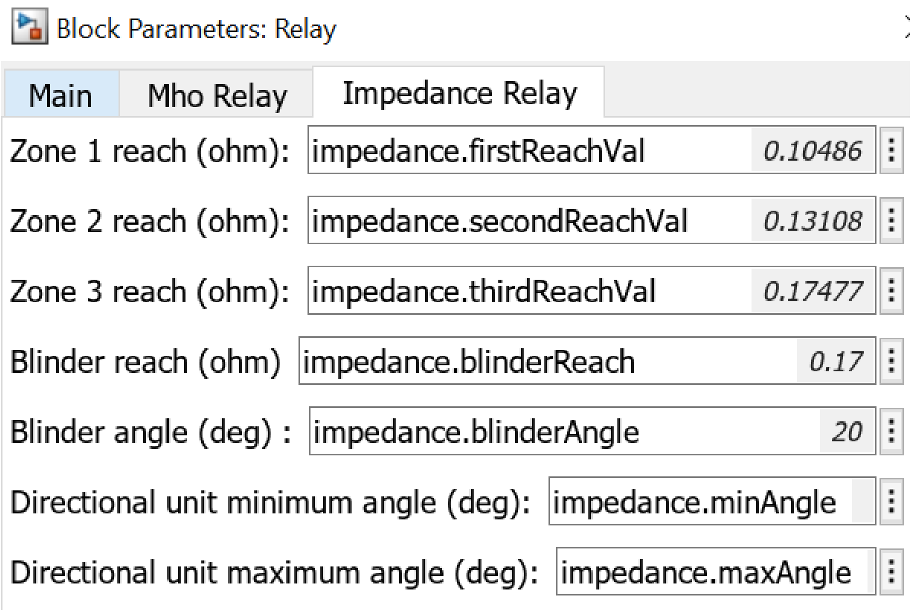


Fig-7: Blinder block parameters

3.3.2 *Zone Selector*

Zone selector is a masked block used for the selection of zones in the blinder region. Three different zones are created in the transmission line on the basis of impedance offered at different locations.

According to the impedance seen by the relay, it checks this value with its predetermined value and if the fault impedance is less, than relay starts its action and provides the trip signal.

Operating time in all the three zones are different like, for the fault impedance falling in the zone-1 than relay acts immediately with almost no time delay, while there will be some delay in zone-2 and subsequently in the zone-3.

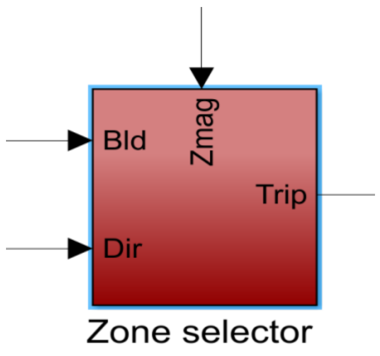


Fig-8: Zone selector block

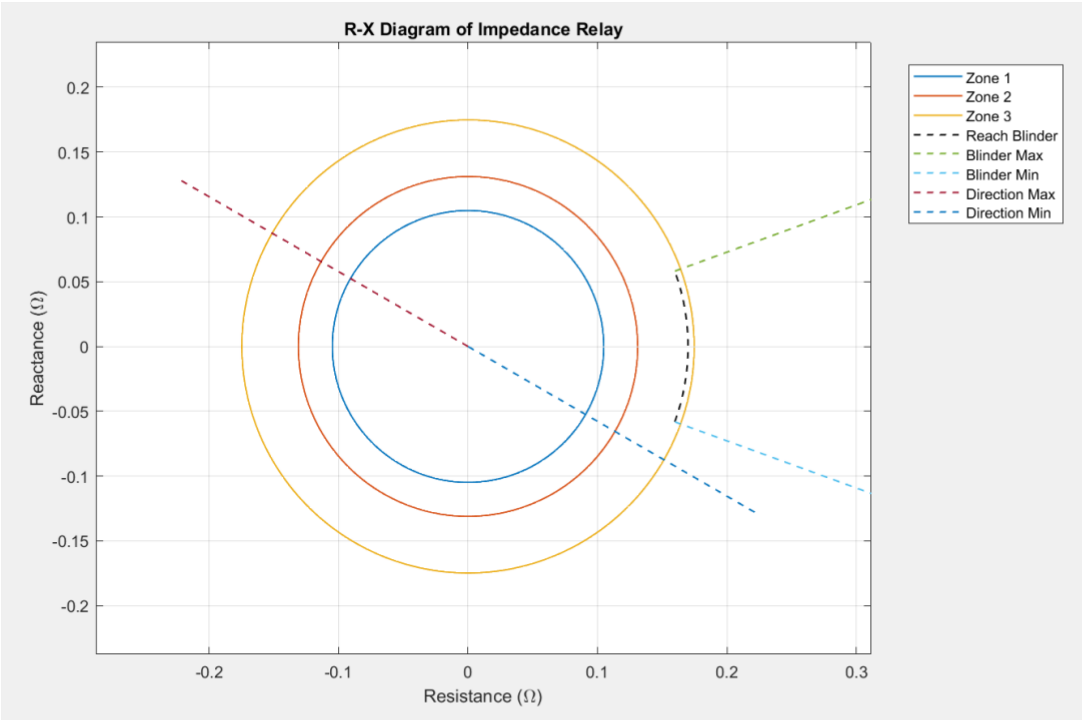


Fig-9: Different zones in the relay

3.3.3 *Directional Unit block*

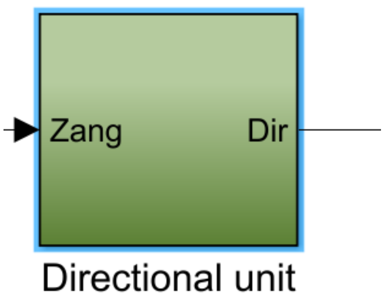


Fig-10: Directional unit

From the name of this block, we can infer about its characteristics. It checks the direction of the current and according to which restricts, if the current is in opposite direction of its working, or allow if the current is in same direction of its specified one.

Directional relay is helpful as it gives an extra edge over bidirectional relay like its selectivity nature allows to isolate the healthy system from the faulty one, similarly its coordination with other protective equipment like circuit breaker etc, is well pronounced than the bidirectional counterparts.

Other than these there are some different type of blocks are also used like radian to degree converter for the angles while calculating the impedance.

3.4 Working

As discussed earlier, Impedance or Mho relay admits two inputs, so in this block as well, two inputs i.e., Current and Voltage has been given into the relay block. This sensed current and voltage is than forwarded for the Fourier analysis in the Fourier analysis block. After the Fourier analysis, one part of this outputs is fed for the conversion from polar to complex form. Other part of this output if fed to the comparator through a gain which compares these values to a predefined threshold values of current and voltage, these threshold values are given as the limit of relays. The output of the comparator is given to an AND gate, input of whom is the output of both of the comparators. Output of this AND gate is used as the enabling signal to the succeeding blocks.

In our model we have used only impedance relay so we will focus only on the working of impedance relay.

Now, after enabling and conversion, working of actual relay starts. After the conversion of voltage and current form polar to complex form, it is the time to estimate the impedance which is the principle behind this relay.

The fault in the transmission line can be phase to ground or phase to phase and hence we need to calculate both type of cases. Figure below is the block diagram of such type of an impedance estimator which estimates the value of impedance at the location of fault form the position of relay in transmission line. Along with the estimation of impedance, there is also a block which estimates the blinder region of relay and relays acts according to it.

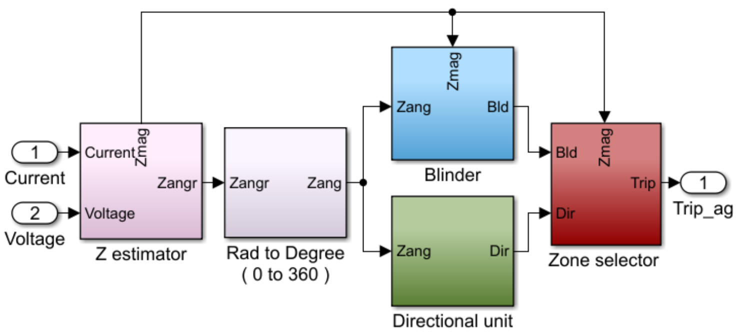


Fig-11: Impedance estimator

CHAPTER 4

Fault detection scheme

4.1 Working

Power grid is acting as 3 phase AC voltage source providing ideal fundamental sinusoidal voltage having frequency (FREQ = 50Hz) and phase-shift (SHIFT = 0). Voltage is given as an input to the 3 phase two winding transformer. A three-phase two-winding voltage transformer is a specific type of transformer used in power systems for measuring and monitoring voltage levels. It is a stepped down voltage transformer (11kv / 440v). It also minimizes the redundancy due to fluctuation of voltage levels and provide accurate data.

Transformer have two output ports:

Lower port is to provide ground voltage in this case (~ 0 v)

Upper port provides 3 phase sinusoidal voltage.

The Voltage sensor block represents an ideal three-phase voltage sensor. It measures voltage between two three-phase electrical nodes and outputs a three-element PS (power system) vector element. The sensor block have two output port, lower port is grounded and upper port sends the 3 phase voltages data through the power system converter. Simulink-Power System Converter block to connect Simulink sources or other Simulink blocks to the inputs of a physical network. It can also be used to convert an input signal into physical signal.

The captured voltage data is (Demux) and each element is passed through the transfer function block which take sensor voltage as input and using $\frac{1}{V_{sensor}}$ gives output and then 3 element is further (Mux) and value is capture and send to the impedance relay.

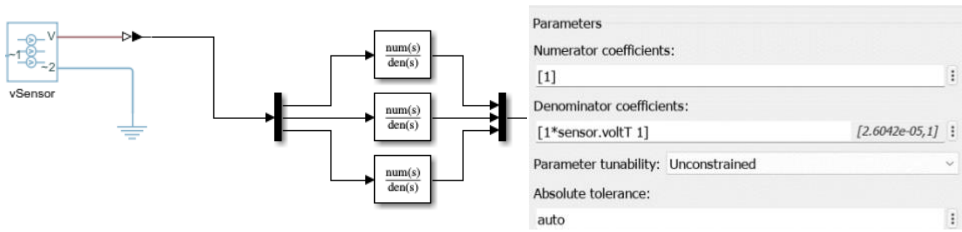


Fig-1: Voltage Transfer function and its parameter

Output voltage from the transformer is connected to the circuit breaker block. The block represents three-phase circuit breaker controlled by an external control signal V_T. The breaker is closed if voltage V_T is less than the threshold. If V_T rises above the threshold value (0.5 v), each phase is disconnected in turn as its current crosses zero. It opens when current crosses zero.

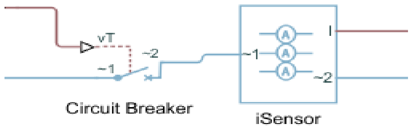


Fig-2: Circuit Breaker & current sensor

If circuit breaker is open then there is no signal sent to the input of current sensor. Initially, circuit breaker is closed and signal is sent as input, there are two output port lower port is connected through transmission line with a connected load at the end. Now, current at different point on transmission line is sensed and the upper blocked is connected to (Demux) which convert single to 3 Phase current element each of which is connected to a mathematical transfer function $\frac{1}{(I_{sensor})}$ gives output and then 3 element is further (Mux) and value is capture and send to the impedance relay.

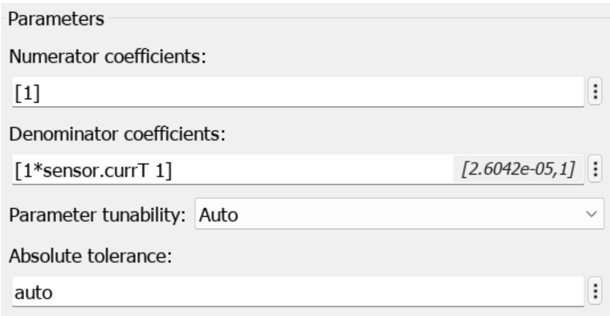


Fig-3: Parameter of Current Transfer Function

Distance protection relay block is connected which is also known as impedance relay. Implement a distance protection relay with impedance relay characteristics and mho relay characteristics. The block accepts three-phase voltage (line to ground) and three-phase current. In the event of a fault, the block generates a trip signal that can be used to trigger the circuit breaker. The directional relay operates based on the principle of directional sensing, which involves determining the direction of current flow in the power system.

The Z-estimator block calculates the value of impedance. The Blinder block set up the trip signal which also prevents unnecessary tripping of circuit breaker. The impedance is used to determine the distance to the fault location along the transmission line.

Distance protection is divided into multiple zones, each corresponding to a different range of distances from the relay. The zones are designed to create a graded response, with each zone representing a different level of severity or proximity to the relay. There are typically three distance protection zones.

Zone 1: *Immediate Trip:* This zone is the closest to the relay and is set for immediate tripping for severe faults**.** *High Speed:* Provides high-speed protection to clear faults close to the relay**.**

Zone 2: *Time Delay:* Set with a time delay compared to Zone 1 to allow for fault clearance by Zone 1. *Intermediate Speed:* Slower compared to Zone 1 but faster than Zone 3.

Zone 3: *Extended Time Delay:* Set with a more extended time delay to allow coordination with Zones 1 and 2. *Slower Operation:* Designed to provide backup protection, allowing the upstream relays to operate first.

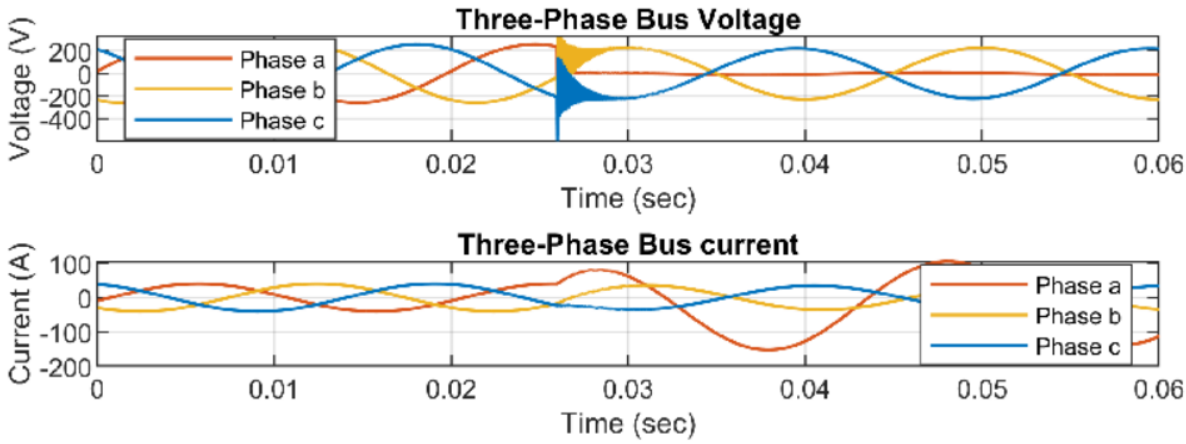
Direction block is used along with distance protection relay helps to separate the healthy part of system from faulty part. Now, Zone protection block is used in the blinder region which compares the impedance from the predetermined value. If value of impedance is lesser than predetermined value then it will send trip signal to the circuit breaker, according to the fault point on the transmission line relay will function with delay.

As the Circuit Breaker receives the trip signal from the relay it will breakdown the contacts from the grid until healthy condition is retrieved.

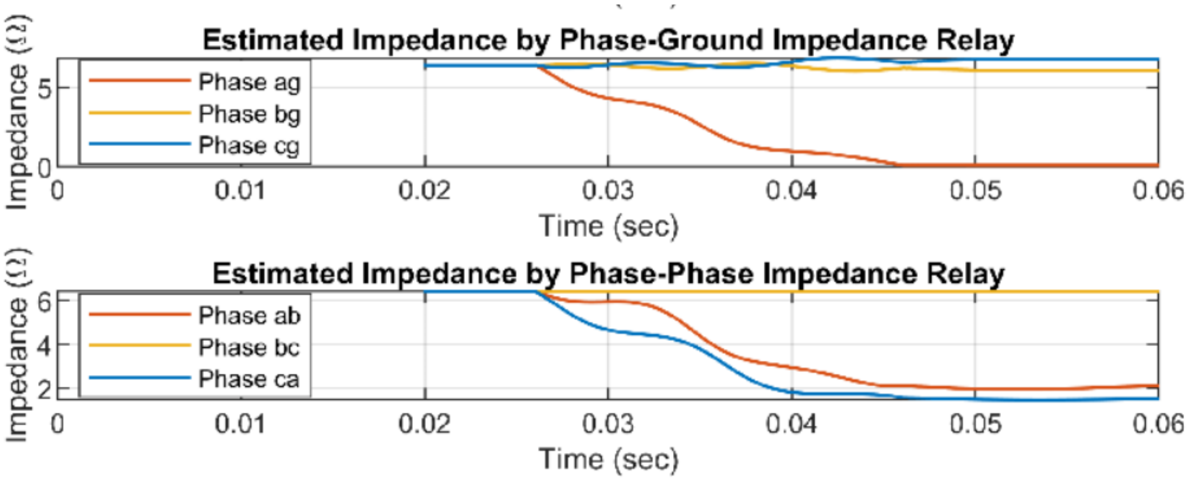
4.2 Plot

4.2.1 Single phase to ground fault

A single-phase to ground (a-g) fault is initiated on the transmission line with a fault initiation time of 0.056 sec. To estimate the fundamental component of voltage and current signal, this example uses full cycle Fourier analysis.



In the above system fault occur in a phase as the fault occurs near 0.025 second $V_a = 0$ and there is some instability in other phases. However current is non zero rather it have some turbulent rise and fault $I_a \neq 0$.



Above plot shows as soon as fault occurs in a phase phase-ground impedance reaches to zero. Phase ab & ca impedance boils down to zero. This phenomenon occurs as because the faulty phase voltage becomes zero as soon as fault occurs. Since impedance is directly proportional to voltage that's why impedance property is similar to voltage one.

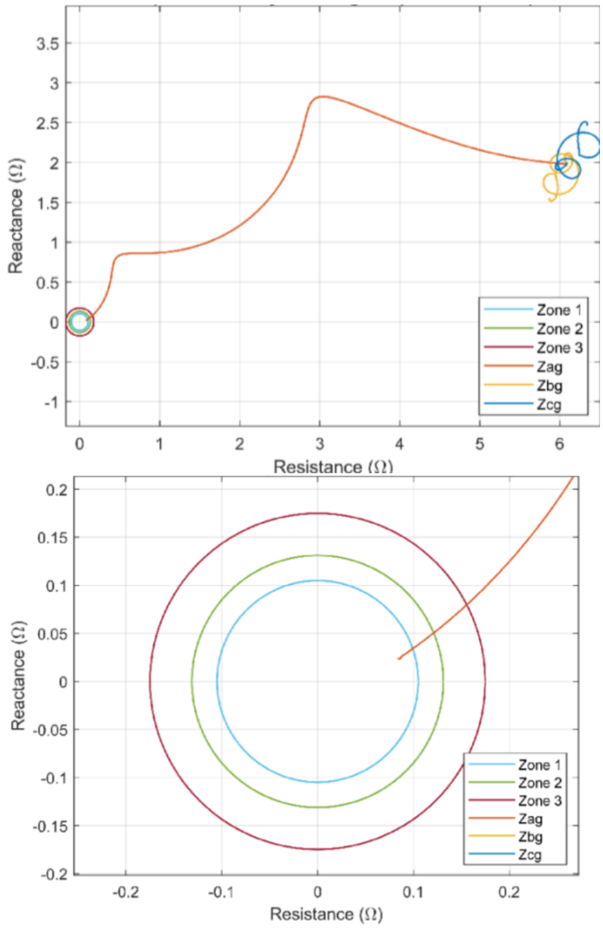
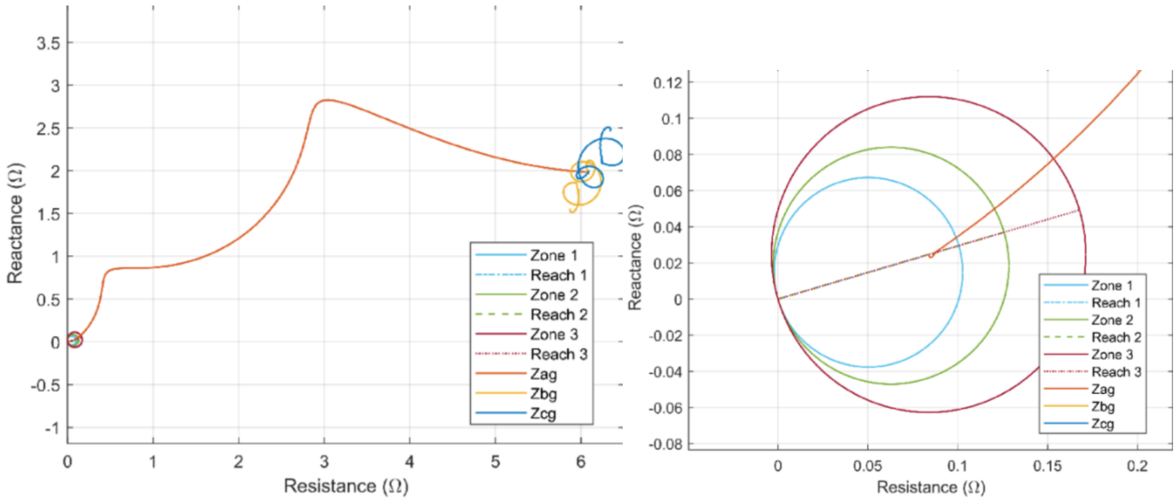


Fig-4: Impedance Relay R-X diagram
(Phase to Ground)

Fig-5 Mho Relay R-X diagram (Phase to Ground)



4.2.2 Three phase to ground fault

A three-phase to ground fault (a-b-c-g) is initiated in the transmission line. The plot below shows the estimated impedance for three-phase to ground fault on the R-X diagram of the phase-phase Mho relay. This figure shows that the phase-phase estimated impedance decreases and reaches zone 1 of the relay.

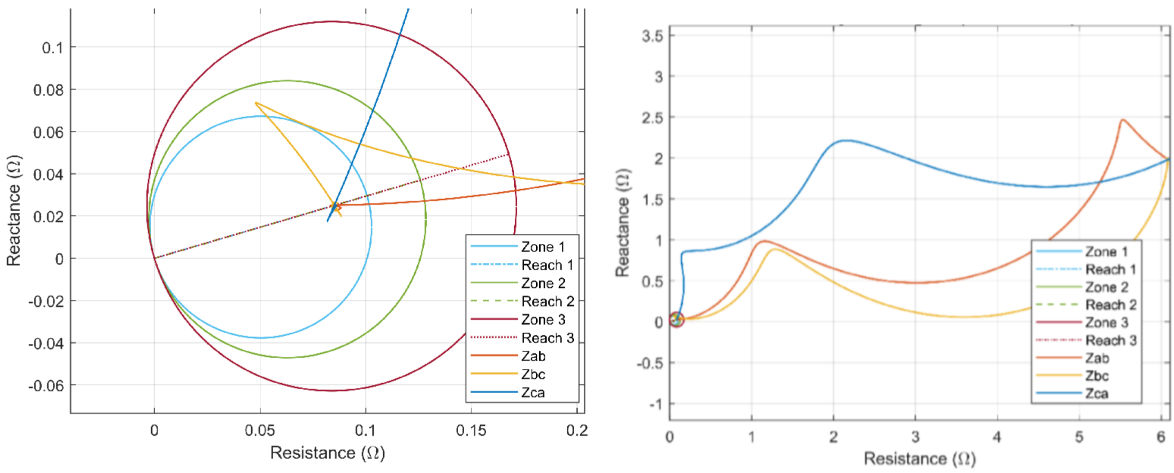


Fig-6: Mho Relay R-X diagram (Phase to Ground)

CHAPTER 5
CONCLUSION

5.1 Overview

The real-time simulation of relays in power system is crucial for several reasons. The conclusion from the making of this project is as follows:

5.1.1 Accuracy and Reliability:

Real- time simulation ensures that the relay models accurately represent their behavior in a live power system. This level of accuracy is essential for the testing and validation protection schemes, ensuring that relays respond reliably to various fault conditions.

5.1.2 System Stability and Security:

By simulating relays in real-time, it becomes possible to assess the impact of relay operations on the overall stability and security of the power system. Identifying potential issues in advance allows for the implementation of corrective measures to prevent cascading failures and enhance the system's resilience.

5.1.3 Performance Evaluation:

Real-time simulation enables a comprehensive evaluation of relay performance under dynamic and transient conditions. This includes assessing response times, coordination between different relays, and the effectiveness of protection schemes in maintaining system integrity.

5.1.4 Training and Operator Preparedness:

Utilizing real-time relay simulation in training scenarios provides operators with a realistic environment to enhance their skills. This proactive approach helps operators become familiar with various relay operations and improve their ability to respond effectively during actual system events. Many of the practices or operations that is difficult to operate on real relay, can be done on this relay simulation.

5.1.5 Cost Savings and Risk Mitigation:

Identifying and rectifying issues during the simulation phase is significantly more cost-effective than dealing with unexpected problems in a live power system. Real-time simulation helps mitigate risks associated with relay missed operations, reducing the potential for equipment damage and costly downtime.

5.1.6 Innovation and System Optimization:

Real-time simulation facilitates the exploration of innovative relay designs and protection strategies. This fosters continuous improvement and optimization of power system protection, contributing to the advancement of the field and the development of more resilient and efficient systems.

5.1.7 Regulatory Compliance:

Meeting regulatory requirements and standards is paramount in the power industry. Real-time simulation aids in demonstrating compliance with industry standards, ensuring that relay devices adhere to specified performance criteria and contribute to the overall reliability and safety of the power grid.

In conclusion, real-time simulation of relays in power systems is indispensable for ensuring the reliability, stability, and security of electrical networks. This approach not only enhances the accuracy of protection schemes but also provides a cost-effective means of identifying and addressing potential issues, ultimately contributing to the overall efficiency and safety of power systems.

5.2 Future Scope

Our model is based on the MATLAB/Simulink software only. Our next task is to implement this model on the real relay and first see the characteristics of the relay that we have prepared in our project. Many of the difficulties that Engineers face while working with the real relay is not been shown in this model and hence after seeing the characteristics of real relay, we can implement that properties in this model as well to make it more realistic and accurate to the real life scale.

Our next goal is also t implement this MATLAB/Simulink model on to the advanced real time software i.e., Hypersim.

5.2.1 Hypersim

"Hypersim" typically refers to a real-time digital simulator used in the field of power systems and electrical engineering. Real-time simulators are tools that replicate the behavior of a physical system in real time, allowing engineers to study and test various scenarios without the need for an actual physical setup. These simulations are crucial for research, development, and testing in fields such as power systems, control systems, and communication systems.

Here are some key points related to the concept of "Hypersim":

5.2.1.1 Real-Time Simulation

Hypersim is known for its real-time simulation capabilities, which means it can execute simulations at the same rate as the actual physical processes it is emulating.

5.2.1.2 Power Systems Simulation:

It is often used in the context of power systems simulation, where it can model and simulate the behavior of electrical networks, including generators, transformers, relays, and other power system components.

5.2.1.3 Hardware-in-the-Loop (HIL) Testing:

Hypersim and similar real-time simulators are commonly used for Hardware-in-the-Loop testing. This involves connecting the simulator to actual hardware components, such as relays or controllers, to validate their performance in a simulated environment.

5.2.1.4 Training and Research:

These simulators are valuable for training operators and engineers and for conducting research on various aspects of power systems, such as protection schemes, fault analysis, and system stability.

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