

THREE PHASE TRANSMISSION LINE FAULT ANALYSIS BY USING MATLAB

**A Thesis submitted in partial fulfillment of the requirements for the Award
of Degree of
Bachelor of Science in Electrical and Electronic Engineering**

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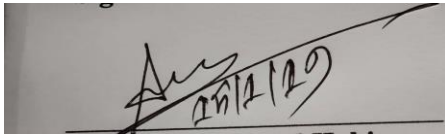
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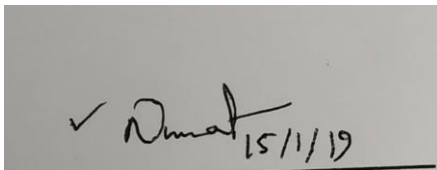
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DECLARATION

The thesis entitled “THREE PHASE TRANSMISSION LINE FAULT ANALYSIS BY USING MATLAB SIMULATION” submitted by **Name: Md. Azizul Hakim**, ID No: 153-33-2983, Session: Fall 2015 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on December 2018.

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ABSTRACT

Power system fault analysis is a process which determines the bus voltages and line currents during the occurrence of various types of faults. Faults on power systems can be divided into three-phase balanced faults and unbalanced faults. Three types of unbalanced fault occurrence on power system transmission lines are single line to ground faults, line to line faults, and double line to ground faults. Fault studies are used to select and set the proper protective devices and switchgears. The determination of the bus voltages and line currents is very important in the fault analysis of power system. The process consists of various methods of mathematical calculation which is difficult to perform by hand. The calculation can be easily done by computer which is generated by a Simulink developed using MATLAB. However, in the conventional short circuit study there arises an error while doing Y-bus to Z-bus inversion for a big bus system. To minimize the error, this paper provides a solution which is solved through “MATLAB SIMULINK”.

CHAPTER 1

1.1 Introduction

When different types of fault occurs in power system then in the process of transmission line fault analysis, determination of bus voltage and the rms line current are possible. While consulting with the power system the terms bus voltage and rms current of line are very important. In case of three phase power system mainly two faults occurs, three phase balance fault and unbalance fault on transmission line of power system, such as line to ground fault, double line to ground fault and double line fault. The transmission line fault analysis helps to select and develop a better for protection purpose. For the protection of transmission line we place the circuit breakers and its rating is depends on triple line fault.

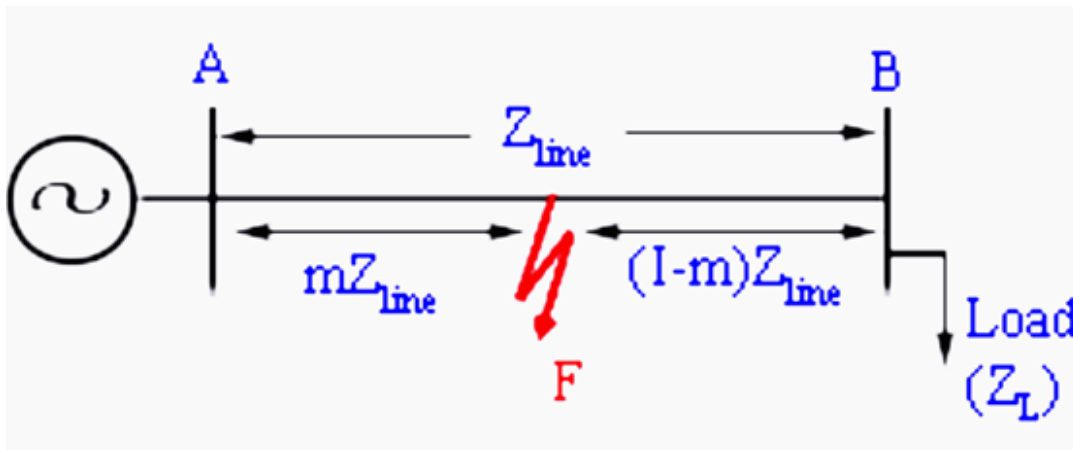


Figure: 1.1 Transmission line fault

The reason behind is that the triple line fault current is very high as compare to other fault current. Hence by using MATLAB simulation in computer, the analysis of transmission line fault can be easily carried out. The main purpose of this paper is to study the general fault types which are balance and unbalance faults of transmission line in the power system. Also to perform the analysis and obtain the result of various parameters (voltage, current, power etc) from simulation on those types of fault using MATLAB. A new modeling framework for analysis and simulation of unbalance fault in power system is procedure includes the frequency information in dynamical models and produces approximate non-linear models that are well adopted for analysis and simulation. The transformer model includes saturation. The parameters have been

obtained from practical or experimental measurements. From the study it is seen that sags can produce transformer saturation when voltage recovers. This leads to produce an inrush current that is similar to inrush current produced during the transformer energizing. The study point out that the voltage recovery instant can take only discrete value, since the fault-clearing is produced in case of natural current zeroes. The instant of voltage recovery corresponds to the instant of fault clearing. For phase to phase fault and single phase fault, a single point-on-wave of voltage recovery can be defined. On the other hand for two-phase- to-ground and three-phase fault, the recovery takes place in two or three steps. In petrochemical industry, the grounding and ground fault protection are very important factors. For that first it is important to have the proper system grounding for the particular system application, and along with this it is equally important to have the proper protection against the ground-fault.

1.2 Problem of the System

Transmission line protection is an important issue in power system reason behind it is 85-87% fault occur in transmission line. Fault detection & classification is an important step to safeguard power system. an automated analysis approach which can automatically characterized fault and subsequent relay operation is required is fault detection play an important role in damaging equipment due to short circuit and fast detection of fault In any line conduces to quick isolation of faulty line from service and hence protecting it from harmful effect of fault is required. So, the proposed system is required to act fast to the fault condition.

1.3 Objectives of the Thesis

The objective of this project is to study the common fault type which is balance fault of the transmission line in the power system. Secondly is to perform the analysis and obtain the results from simulation on those types of fault using MATLAB. Lastly is to develop a toolbox for power system fault analysis for educational and training purposes.

1. To fault detection in three phase transmission line.
2. To fault classification in three phase transmission line.
3. To fault location in three phase transmission line.

4. To best fault calculation method to be implemented for calculation.
5. To Calculation of three phase transmission line fault current & voltage.

1.4 Project/Thesis planning

Task performed

- i. Feasibility study
- ii. Planning of the research method to be adopted.

In this period of time, project/thesis planning was done by the researcher & the feasibility study about the topic and the methodology to be used was performed. Planning for primary and secondary research method which will be adopted was done in this period of time again for this purpose various book, E-book, library resource was used by the researcher.

1.5 Benefits of a Short Circuit Analysis

Performing a Short Circuit Study provides the following benefits:

- Reduces the risk a facility could face and help avoid catastrophic losses.
- Increases the safety and reliability of the power system and related equipment.
- Evaluates the application of protective devices and equipment.
- Identifies problem areas in the system.
- Identifies recommended solutions to existing problems.

1.6 Report Outline

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Types of Transmission Line Fault

Chapter 4: Fault Calculation

Chapter 5: MATLAB Simulation

Chapter 6: MATLAB Simulation Result & Discussion

Chapter 7: Calculation

CHAPTER 2

Literature Review

2.1 Introduction

Electric power is generated, transmitted and distributed by large interconnected power systems. Any power system can be analyzed by calculating the system voltages and currents under normal & abnormal scenarios.

The fault currents caused by short circuits may be several orders of magnitude larger than the normal operating currents and are determined by the system impedance between the generator voltages and the fault, under the worst scenario if the fault persists, it may lead to long-term power loss, blackouts and permanent damage to the equipment. To prevent such an undesirable situation, the temporary isolation of the fault from the whole system is necessary as soon as possible. This is accomplished by the protective relaying system.

To complete this task successfully, fault analysis has to be conducted in every location assuming several fault conditions. The goal is to determine the optimum protection scheme by determining the fault currents & voltages. In reality, power system can consist of thousands of buses which complicate the task of calculating these parameters without the use of computer software's such as Matlab. In 1956, L.W. Comber and D. G. Lewis proposed the first fault analysis program.

Many existing texts offer an extensive analysis in fault studies and calculation. Two worth mentioning are Analysis of Faulted Power System by Paul Anderson and Electrical Power Transmission System Engineering Analysis and Design by Turan Gonen. In addition to offer a very illustrative and clear analysis in the fault studies, they also offer an impressive guideline for the power systems analysis understanding in general.

2.2 Method of Analysis

In order to analyze any unbalanced power system, C.L. Fortescue introduced a method called symmetrical components in 1918 to solve such system using a balanced representation. This method is considered the base of all traditional fault analysis approaches of solving unbalanced power systems. The theory suggests that any unbalanced system can be represented by a number of balanced systems equal to the number of its phasors. The balanced systems representations are called symmetrical components.

2.3 Review of Fault

In an electric power system, a fault is unusual electric current. A short circuit is also considered as a fault in which current bypasses the normal load. An open-circuit fault occurs if a circuit is interrupted by some failure. In three-phase systems, a fault may involve one or more phases and ground, or may occur only between phases. In a "ground fault" or "earth fault", charge flows into the earth. The prospective short circuit current of a fault can be calculated for power systems. In power systems, protective devices detect fault conditions and operate circuit breakers and other devices to limit the loss of service due to a failure.

CHAPTER 3

Types of Transmission Line Fault

3.1 Introduction

As discuss above in three-phase transmission line of power system mainly two types of fault occurs, balance fault which is also called symmetrical fault and unbalance fault called as unsymmetrical fault. But this paper only deals with the unsymmetrical fault which mainly occurs between two or three conductors of the three-phase system or some time in between conductor and ground. Contingent on this the unsymmetrical faults can be characterized into fundamental three sorts:-

- Single Line to Ground fault.
- Double Line fault.
- Double Line to Ground fault.

The frequency of occurrence of the single line to ground fault is more in the three phase system followed by the L-L fault, 2L-G fault and three phase fault. During electrical storms these types of fault are occurs which may results to insulator flashover and ultimately affect the power system. To study and analyze the unsymmetrical fault in MATLAB there is a need of develop a network of positive, negative and zero sequence. In this paper us analysis positive, negative and zero sequence voltage and current of buses at different fault situation. In addition to this we analyze the active and reactive power and rms bus current and voltage of the system at various fault condition.

3.2 Symmetrical Fault

A symmetric or balanced fault affects each of the three phases equally. In transmission line faults, roughly 5% are symmetric. This is in contrast to an asymmetrical fault, where the three phases are not affected equally.

There are two kinds of symmetrical fault

- three-phase faults
- three-phase faults with ground fault

3.2.1 Three-Phase Faults



Figure: 3.1 Three-phase faults

3.2.2 Three-Phase Faults with Ground Fault

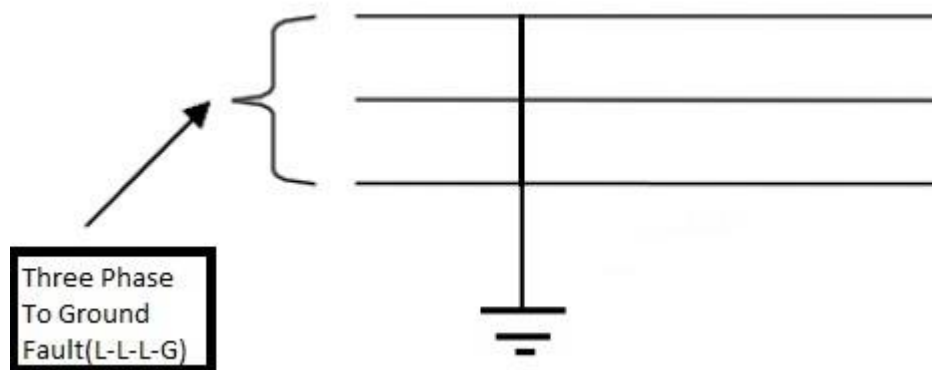


Figure: 3.2 Three-phase faults with ground fault

3.3 Unsymmetrical Fault

An asymmetric or unbalanced fault does not affect each of the three phases equally. 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 contact, for example due to a broken 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 come into contact with the ground also commonly due to storm damage.

There are four types of Unsymmetrical fault:

1. Single line to ground
2. Line to line
3. Double line to ground
4. Line to line with other line to ground

3.3.1 Single Line to Ground

In this type of fault 1 phase gets in contact with the ground so potential then becomes infinite

Boundary condition: $I_{fb}=I_{fc}=0$

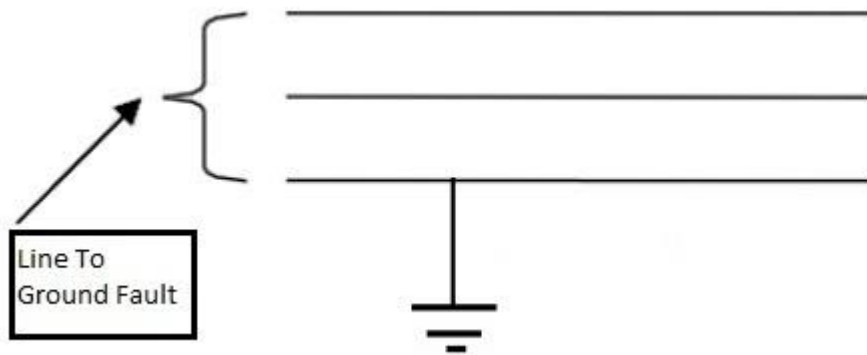


Figure: 3.3 Single line to ground

Below figure shows sequence network which show that the three network must be connected in series

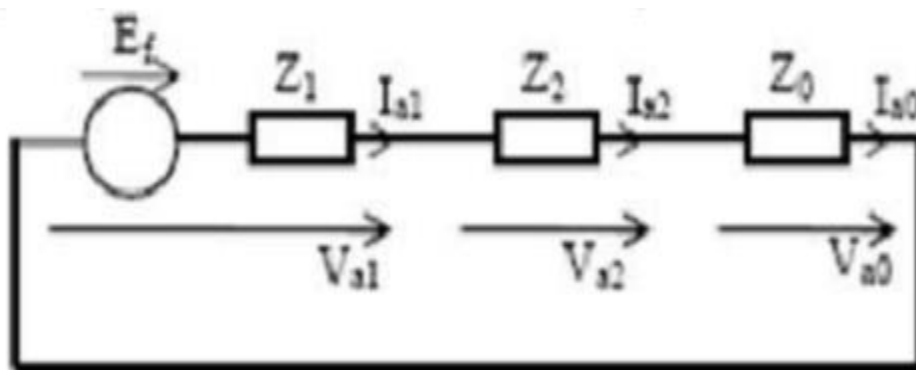


Figure: 3.4 Sequence network of line to ground fault

\

3.3.2 Line to Line

In this type of fault two phases are short circuited

Boundary condition: $I_{fa} = 0$

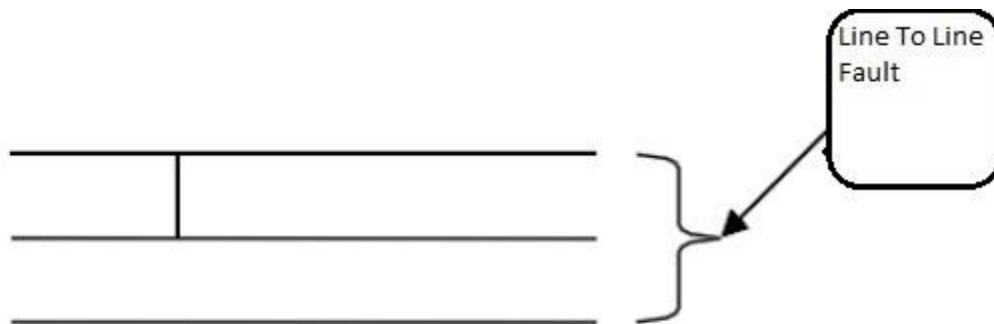


Figure: 3.5 Line to line

The boundary conditions are $I_{a0} = 0$, $I_{a1} + I_{a2} = 0$ & $V_{a1} = V_{a2}$ indicates a sequence network where the positive & negative sequence are in parallel & the zero sequence is open circuited as shown in figure below

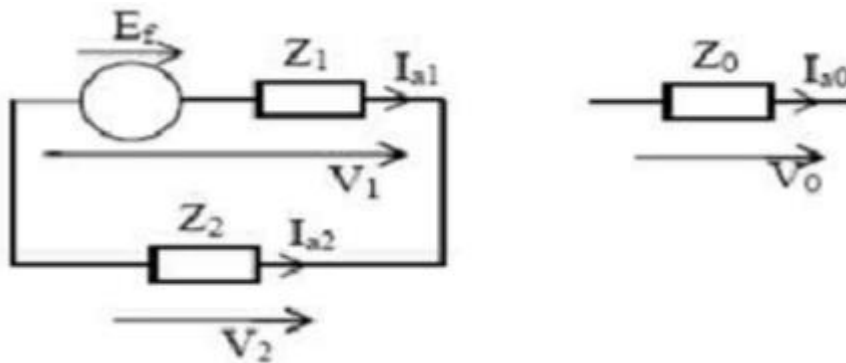


Figure: 3.6 Line to line circuit

3.3.3 Double Line to Ground

It is assumed that the fault has occurred at node k of the network. In this the phase's b and c got shorted through the impedance Z_f to the ground.

Boundary condition: $3I_{fa}=I_{fb}+I_{fc}$

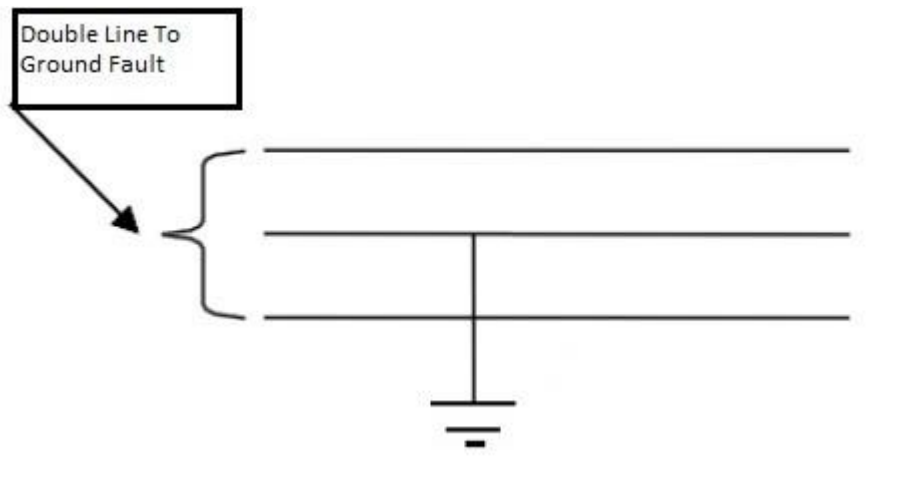


Figure: 3.7 Double line to ground

Under the fault condition $I_a = V_b = V_c = 0$

$I_{a0} + I_{a1} + I_{a2} = 0$

3.3.4 Line to Line with Other Line to Ground

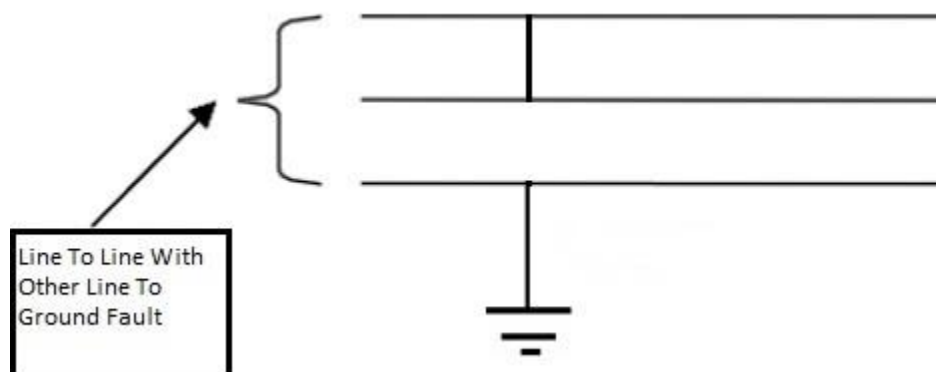


Figure: 3.8 Line to line with other line to ground

CHAPTER 4

Fault Calculation

4.1 Introduction

This chapter describes the mathematical model that is used in the analysis of faulted power systems and the assumptions that are used in this project/thesis analysis.

4.2 Fortescue's Theory

A three-phase balanced fault can be defined as a short circuit with fault impedance called Z_f between the ground and each phase. The short circuit will be called a solid fault when Z_f is equal to zero. This type of fault is considered the most severe short circuit which can affect any electrical system. Fortunately, it is rarely taking place in reality. Fortescue segregated asymmetrical three-phase voltages and currents into three sets of symmetrical components in 1918.

Analyzing any symmetrical fault can be achieved using impedance matrix method or Thevenin's method. Fortescue's theorem suggests that any unbalanced fault can be solved into three independent symmetrical components which differ in the phase sequence. These components consist of a positive sequence, negative sequence and a zero sequence.

4.3 Fault Analysis in Power Systems

In general, a fault is any event, unbalanced situation or any asymmetrical situation that interferes with the normal current flow in a power system and forces voltages and currents to differ from each other. It is important to distinguish between series and shunt faults in order to make an accurate fault analysis of an asymmetrical three-phase system. When the fault is caused by an unbalance in the line impedance and does not involve a ground, or any type of inter-connection between phase conductors it is known as a series fault. On the other hand, when the fault occurs and there is an inter-

connection between phase-conductors or between conductor and ground and/or neutral it is known as a shunt fault.

Statistically, series faults do not occur as often as shunt faults does. Because of this fact only the shunt faults are explained here in detail since the emphasis in this project is on analysis of a power system under shunt faults.

4.3.1 Three-Phase Fault

By definition a three-phase fault is a symmetrical fault. Even though it is the least frequent fault, it is the most dangerous. Some of the characteristics of a three-phase fault are a very large fault current and usually a voltage level equals to zero at the site where the fault takes place.

A general representation of a balanced three-phase fault is shown in Figure. Where F is the fault point with impedances Z_f and Z_g .

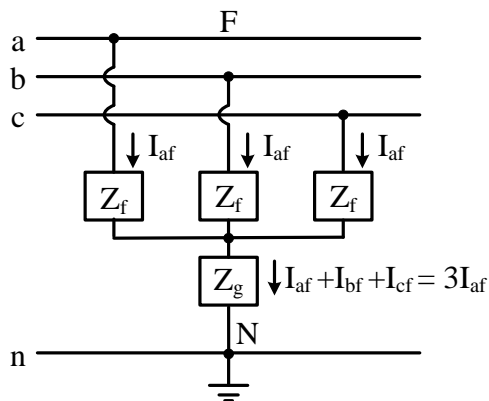


Figure: 4.1 General representation of a balanced three-phase fault

Shows the sequences networks interconnection diagram

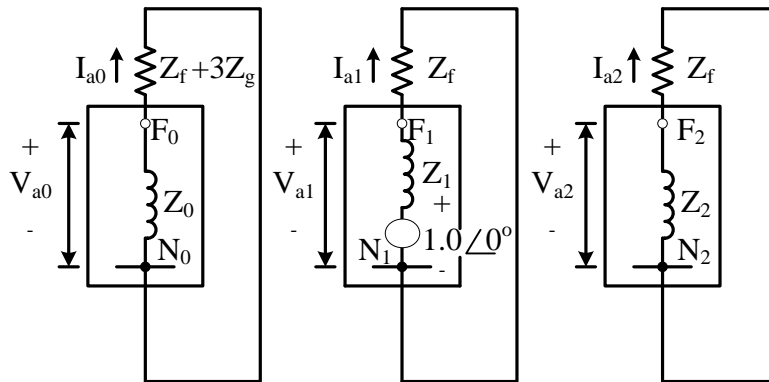


Figure: 4.2 Sequence network diagram of a balanced three-phase fault

It can be noticed that the only one that has an internal voltage source is the positive-sequence network. Therefore, the corresponding currents for each of the sequences can be expressed as

$$\begin{aligned} I_{a0} &= 0 \\ I_{a2} &= 0 \\ I_{a1} &= \frac{1.0\angle 0^\circ}{Z_1 + Z_f} \end{aligned} \quad (3.37)$$

If the fault impedance Z_f is zero,

$$I_{a1} = \frac{1.0\angle 0^\circ}{Z_1} \quad (3.38)$$

If equation is substituted into equation

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ I_{a1} \\ 0 \end{bmatrix} \quad (3.39)$$

Solving Equation 3.39

$$\begin{aligned}
I_{af} &= I_{a1} = \frac{1.0 \angle 0^\circ}{Z_1 + Z_f}, \\
I_{bf} &= a^2 I_{a1} = \frac{1.0 \angle 240^\circ}{Z_1 + Z_f}, \\
I_{cf} &= a I_{a1} = \frac{1.0 \angle 120^\circ}{Z_1 + Z_f}
\end{aligned} \tag{3.40}$$

Since the sequence networks are short-circuited over their own fault impedance

$$\begin{aligned}
V_{a0} &= 0 \\
V_{a1} &= Z_f I_{a1} \\
V_{a2} &= 0
\end{aligned} \tag{3.41}$$

If Equation is substituted into Equation

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ V_{a1} \\ 0 \end{bmatrix} \tag{3.42}$$

Therefore,

$$\begin{aligned}
V_{af} &= V_{a1} = Z_f I_{a1} \\
V_{bf} &= a^2 V_{a1} = Z_f I_{a1} \angle 240^\circ \\
V_{cf} &= a V_{a1} = Z_f I_{a1} \angle 120^\circ
\end{aligned} \tag{3.43}$$

The line-to-line voltages are

$$\begin{aligned}
V_{ab} &= V_{af} - V_{bf} = V_{a1} (1 - a^2) = \sqrt{3} Z_f I_{a1} \angle 30^\circ \\
V_{bc} &= V_{bf} - V_{cf} = V_{a1} (a^2 - a) = \sqrt{3} Z_f I_{a1} \angle -90^\circ \\
V_{ca} &= V_{cf} - V_{af} = V_{a1} (a - 1) = \sqrt{3} Z_f I_{a1} \angle 150^\circ
\end{aligned} \tag{3.44}$$

If Z_f equals to zero,

$$\begin{aligned}
I_{af} &= \frac{1.0 \angle 0^\circ}{Z_1} \\
I_{bf} &= \frac{1.0 \angle 240^\circ}{Z_1}, \\
I_{cf} &= \frac{1.0 \angle 120^\circ}{Z_1}
\end{aligned} \tag{3.45}$$

The phase voltages becomes,

$$\begin{aligned} V_{af} &= 0 \\ V_{bf} &= 0 \\ V_{cf} &= 0 \end{aligned} \tag{3.46}$$

And the line voltages,

$$\begin{aligned} V_{a0} &= 0 \\ V_{a1} &= 0 \\ V_{a2} &= 0 \end{aligned} \tag{3.47}$$

4.3.2 Single Line-to-Ground Fault

The single line-to-ground fault is usually referred as “short circuit” fault and occurs when one conductor falls to ground or makes contact with the neutral wire. The general representation of a single line-to-ground fault is shown in Figure. Where F is the fault point with impedances Z_f . the sequences network diagram. Phase a is usually assumed to be the faulted phase, this is for simplicity in the fault analysis calculations.

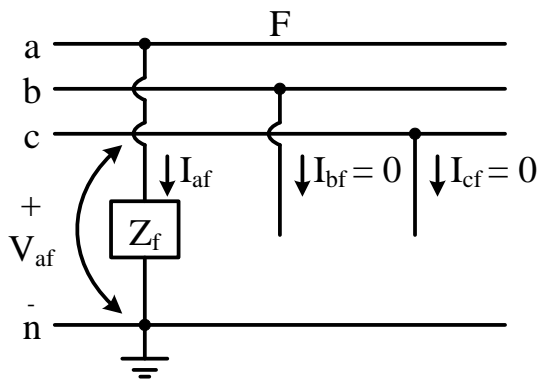


Figure: 4.3 General representation of a single line-to-ground fault.

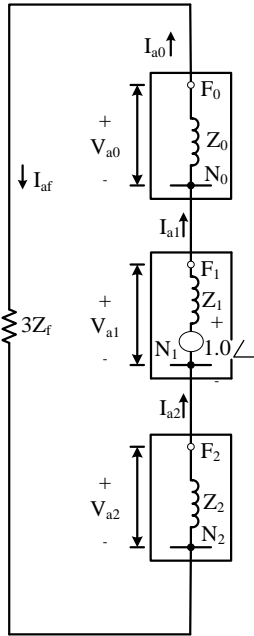


Figure: 4.4 Sequence network diagram of a single line-to-ground fault.

Since the zero-, positive-, and negative-sequence currents are equal as it can be observed in Figure. Therefore,

$$I_{a0} = I_{a1} = I_{a2} = \frac{1.0\angle 0^\circ}{Z_0 + Z_1 + Z_2 + 3Z_f} \quad (3.48)$$

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad (3.49)$$

Solving Equation the fault current for phase a is

$$I_{af} = I_{a0} + I_{a1} + I_{a2} \quad (3.50)$$

it can also be

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \quad (3.51)$$

From Figure 3.10 it can be observed that,

$$V_{af} = Z_f I_{af} \quad (3.52)$$

The voltage at faulted phase a can be obtained by substituting Equation 3.49 into Equation 3.52. Therefore,

$$V_{af} = 3Z_f I_{a1} \quad (3.53)$$

but,

$$V_{af} = V_{a0} + V_{a1} + V_{a2} \quad (3.54)$$

Therefore,

$$V_{a0} + V_{a1} + V_{a2} = 3Z_f I_{a1} \quad (3.55)$$

With the results obtained for sequence currents, the sequence voltages can be obtained from

$$\begin{bmatrix} V_{a0} \\ V_{b1} \\ V_{c2} \end{bmatrix} = \begin{bmatrix} 0 \\ 1.0 \angle 0^\circ \\ 0 \end{bmatrix} - \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad (3.56)$$

By solving Equation

$$\begin{aligned} V_{a0} &= -Z_0 I_{a0} \\ V_{a1} &= 1.0 - Z_1 I_{a1} \\ V_{a2} &= -Z_2 I_{a2} \end{aligned} \quad (3.57)$$

If the single line-to-ground fault occurs on phase b or c, the voltages can be found by the relation that exists to the known phase voltage components,

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \quad (3.58)$$

as

$$\begin{aligned} V_{bf} &= V_{a0} + a^2 V_{a1} + a V_{a2} \\ V_{cf} &= V_{a0} + a V_{a1} + a^2 V_{a2} \end{aligned} \quad (3.59)$$

4.3.3 Line to Line Fault

A line-to-line fault may take place either on an overhead and/or underground transmission system and occurs when two conductors are short-circuited. One of the characteristic of this type of fault is that its fault impedance magnitude could vary over a wide range making very hard to predict its upper and lower limits. It is when the fault impedance is zero that the highest asymmetry at the line-to-line fault occurs.

The general representation of a line-to-line fault is shown in Figure 3.12 where F is the fault point with impedances Z_f . Figure 3.13 shows the sequences network diagram. Phase b and c are usually assumed to be the faulted phases; this is for simplicity in the fault analysis calculations,

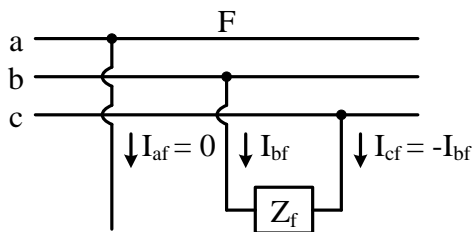


Figure: 4.5 Sequence network diagram of a line-to-line fault.

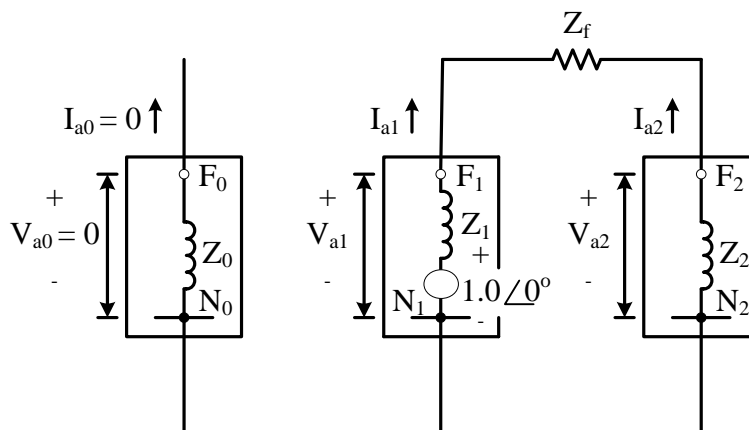


Figure: 4.6 Sequence network diagram of a single line-to-ground fault.

From Figure 3.13 it can be noticed that

$$I_{af} = 0$$

$$I_{bf} = -I_{cf} \quad (3.60)$$

$$V_{bc} = Z_f I_{bf}$$

And the sequence currents can be obtained as

$$I_{a0} = 0 \quad (3.61)$$

$$I_{a1} = -I_{a2} = \frac{1.0 \angle 0^\circ}{Z_1 + Z_2 + Z_f} \quad (3.62)$$

If $Z_f = 0$,

$$I_{a1} = -I_{a2} = \frac{1.0 \angle 0^\circ}{Z_1 + Z_2} \quad (3.63)$$

The fault currents for phase b and c can be obtained by substituting Equations 3.61 and 3.62 into Equation 3.49

$$I_{bf} = -I_{cf} = \sqrt{3} I_{a1} \angle -90^\circ \quad (3.64)$$

The sequence voltages can be found similarly by substituting Equations 3.61 and 3.62 into Equation 3.56

$$\begin{aligned} V_{a0} &= 0 \\ V_{a1} &= 1.0 - Z_1 I_{a1} \\ V_{a2} &= -Z_2 I_{a2} = Z_2 I_{a1} \end{aligned} \quad (3.65)$$

Also substituting Equation 3.65 into Equation 3.58

$$\begin{aligned} V_{af} &= V_{a1} + V_{a2} = 1.0 + I_{a1}(Z_2 - Z_1) \\ V_{bf} &= a^2 V_{a1} + a V_{a2} = a^2 + I_{a1}(a Z_2 - a^2 Z_1) \\ V_{cf} &= a V_{a1} + a^2 V_{a2} = a + I_{a1}(a^2 Z_2 - a Z_1) \end{aligned} \quad (3.66)$$

Finally, the line-to-line voltages for a line-to-line fault can be expressed as

$$\begin{aligned}
 V_{ab} &= V_{af} - V_{bf} \\
 V_{bc} &= V_{bf} - V_{cf} \\
 V_{ca} &= V_{cf} - V_{af}
 \end{aligned}
 \tag{3.67}$$

4.3.4 Double Line to Ground Fault

A double line-to-ground fault represents a serious event that causes a significant asymmetry in a three-phase symmetrical system and it may spread into a three-phase fault when not clear in appropriate time. The major problem when analyzing this type of fault is the assumption of the fault impedance Z_f , and the value of the impedance towards the ground Z_g . [3]

The general representation of a double line-to-ground fault is shown in Figure 3.14 where F is the fault point with impedances Z_f and the impedance from line to ground Z_g . Figure 3.15 shows the sequences network diagram. Phase b and c are assumed to be the faulted phases, this is for simplicity in the fault analysis calculations. [1]

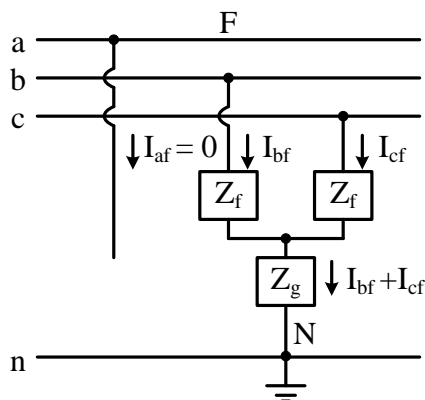


Figure: 4.7 General representation of a double line-to-ground fault.

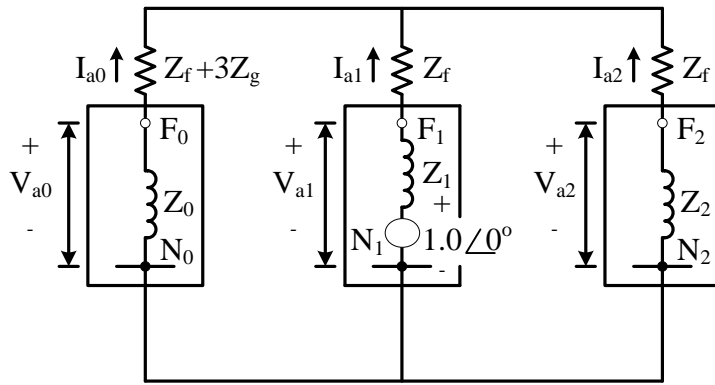


Figure: 4.8 Sequence network diagram of a double line-to-ground fault.

From Figure 3.15 it can be observed that

$$\begin{aligned}
 I_{af} &= 0 \\
 V_{bf} &= (Z_f + Z_g)I_{bf} + Z_g I_{cf} \\
 V_{cf} &= (Z_f + Z_g)I_{cf} + Z_g I_{bf}
 \end{aligned} \tag{3.68}$$

Based on Figure 3.15, the positive-sequence currents can be found as

$$\begin{aligned}
 I_{a1} &= \frac{1.0\angle 0^\circ}{(Z_1 + Z_f) + \frac{(Z_2 + Z_f)(Z_0 + Z_f + 3Z_g)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}} \\
 I_{a2} &= -\left[\frac{(Z_0 + Z_f + 3Z_g)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)} \right] I_{a1} \\
 I_{a0} &= -\left[\frac{(Z_2 + Z_f)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)} \right] I_{a1}
 \end{aligned} \tag{3.69}$$

An alternative method is,

$$\begin{aligned}
 I_{af} = 0 &= I_{a0} + I_{a1} + I_{a2} \\
 I_{a0} &= -(I_{a1} + I_{a2})
 \end{aligned} \tag{3.70}$$

If Z_f and Z_g are both equal to zero, then the positive-, negative-, and zero-sequences can be obtained from

$$I_{a1} = \frac{1.0 \angle 0^\circ}{(Z_1) + \frac{(Z_2)(Z_0)}{(Z_2 + Z_0)}}$$

$$I_{a2} = -\left[\frac{(Z_0)}{(Z_2 + Z_0)}\right]I_{a1} \quad (3.71)$$

$$I_{a0} = -\left[\frac{(Z_2)}{(Z_2 + Z_0)}\right]I_{a1}$$

From Figure 3.14 the current for phase a is

$$I_{af} = 0 \quad (3.72)$$

Now, substituting Equations 3.71 into Equation 3.49 to obtain phase b and c fault currents

$$I_{bf} = I_{a0} + a^2 I_{a1} + a I_{a2} \quad (3.73)$$

$$I_{cf} = I_{a0} + a I_{a1} + a^2 I_{a2}$$

The total fault current flowing into the neutral is

$$I_n = 3I_{a0} = I_{bf} + I_{cf} \quad (3.74)$$

And the sequence voltages can be obtained by using Equation 3.51

$$V_{0a} = -Z_0 I_{a0}$$

$$V_{a1} = 1.0 - Z_1 I_{a1} \quad (3.75)$$

$$V_{a2} = -Z_2 I_{a2}$$

The phase voltages are equal to

$$V_{af} = V_{a0} + V_{a1} + V_{a2}$$

$$V_{bf} = V_{a0} + a^2 V_{a1} + a V_{a2} \quad (3.76)$$

$$V_{cf} = V_{a0} + a V_{a1} + a^2 V_{a2}$$

The line-to-line voltages can be obtained from

$$\begin{aligned} V_{ab} &= V_{af} - V_{bf} \\ V_{bc} &= V_{bf} - V_{cf} \\ V_{ca} &= V_{cf} - V_{af} \end{aligned} \quad (3.77)$$

If $Z_f = 0$ and $Z_g = 0$ then the sequence voltages become, and the positive-sequence current is found by using Equation 3.71.

$$V_{a0} = V_{a1} = V_{a2} = 1.0 - Z_1 I_{a1} \quad (3.78)$$

Now the negative- and zero-sequence currents can be obtained from

$$\begin{aligned} I_{a2} &= -\frac{V_{a2}}{Z_2} \\ I_{a0} &= -\frac{V_{a0}}{Z_0} \end{aligned} \quad (3.79)$$

The resultant phase voltages from the relationship given in Equation 3.78 can be expressed as

$$\begin{aligned} V_{af} &= V_{a0} + V_{a1} + V_{a2} = 3V_{a1} \\ V_{bf} &= V_{cf} = 0 \end{aligned} \quad (3.80)$$

And the line-to-line voltages are

$$\begin{aligned} V_{abf} &= V_{af} - V_{bf} = V_{af} \\ V_{bcf} &= V_{bf} - V_{cf} = 0 \\ V_{caf} &= V_{cf} - V_{af} = -V_{af} \end{aligned} \quad (3.81)$$

CHAPTER 5

MATLAB simulation

5.1 Introduction

The name MATLAB views for Matrix Laboratory. MATLAB was written originally to deliver easy access to matrix software developed by the (Linear method package & Eigen method package projects).MATLAB is a great performance language for technical calculating.it integrates calculation, visualization & programing environment where problem & solution are expressed in familiar mathematical representation. MATLAB has several advantages to conventional computer language example (C, FORTRAN) for solving technical problem.

5.2 Model Of The Power System Parameter List

1. AC voltage source Simulink block.
2. Distributed transmission line Simulink block.
3. Relay Simulink block.
4. Three-Phase Fault Simulink block.
5. Parallel RLC Load Simulink block.
6. Scope Simulink Block.
7. Powergui Simulink Block.

5.2.1 AC Voltage Source Simulink Block

AC voltage source model in Simulink was presented by three-phase ideal sinusoidal voltage source with amplitude of 11000 volts and frequency are 50Hz with three phases lagging respectively other by 120 degrees.

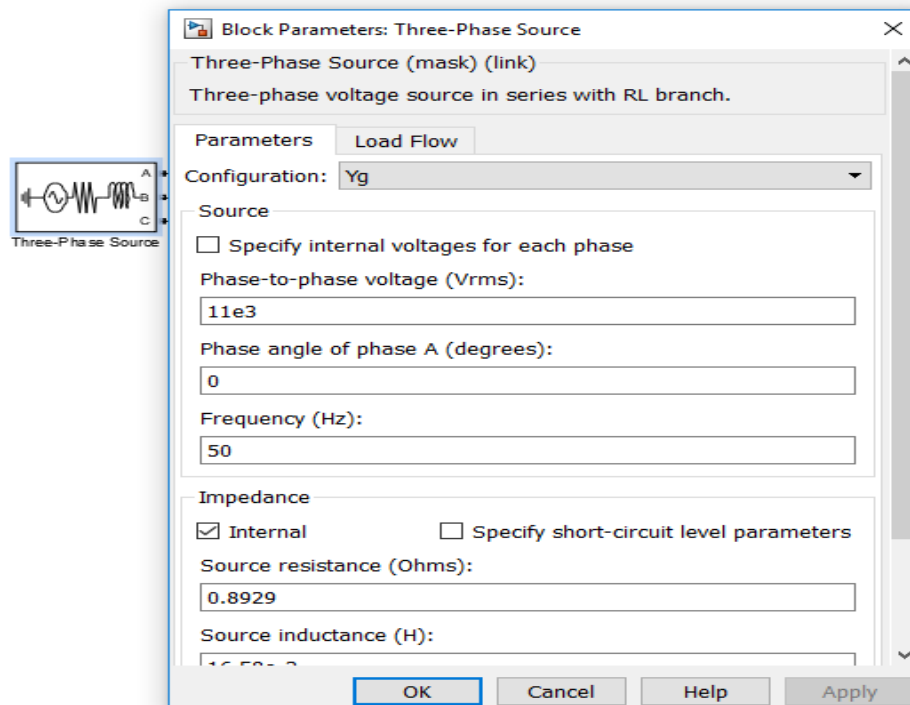


Figure: 5.1 AC voltage source simulink block

5.2.2 Distributed Transmission Line Simulink Block

The Three-Phase PI Section Line blocks implements a balanced three-phase transmission line model with parameters lumped in a PI section. Contrary to the Distributed Parameter Line model where the resistance, inductance, and capacitance are uniformly distributed alongside the line, the Three-Phase PI Section Line block lumps the line parameters in a single PI section as shown in the figure below.

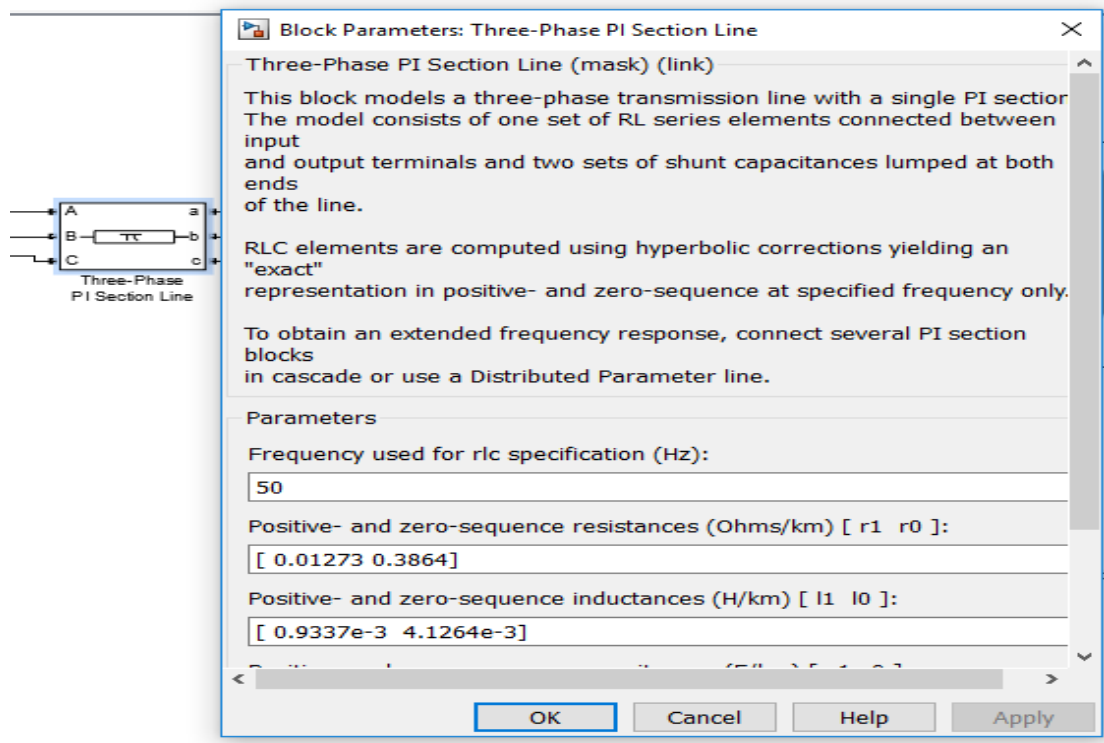


Figure: 5.2 Distributed transmission line simulink block

5.2.3 Relay Simulink Block

The Relay block allows the output to the switch between two specified values. When the relay is on, it remains on up to the input drops below the value of the **Switch off point** parameter. When the relay is off, it remains off until the input exceeds the value of the **Switch on point** parameter. The block accepts one input and generates one output. The **Switch on point** value must be greater than or equal to the **Switch off point**. Specifying a **Switch on point** value greater than the **Switch off point** value models hysteresis, whereas specifying equal values models a switch with a threshold at that value.

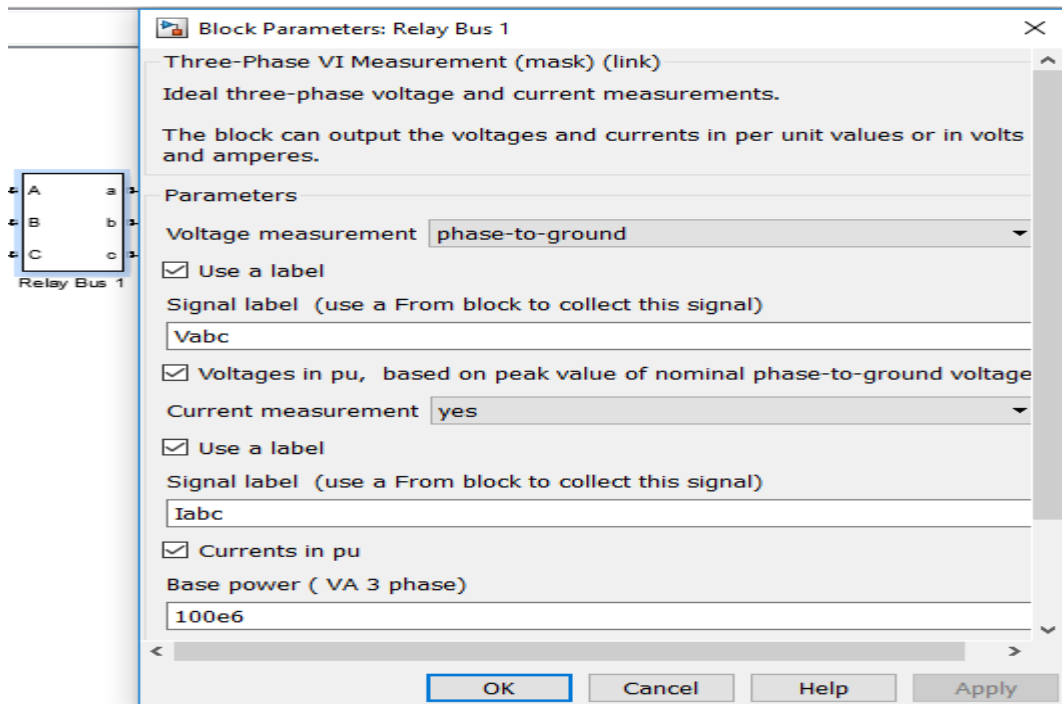


Figure: 5.3 Relay simulink block

5.2.4 Three-Phase Fault Simulink Block

The Three-Phase Fault block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal (external control mode), or from an internal control timer (internal control mode).

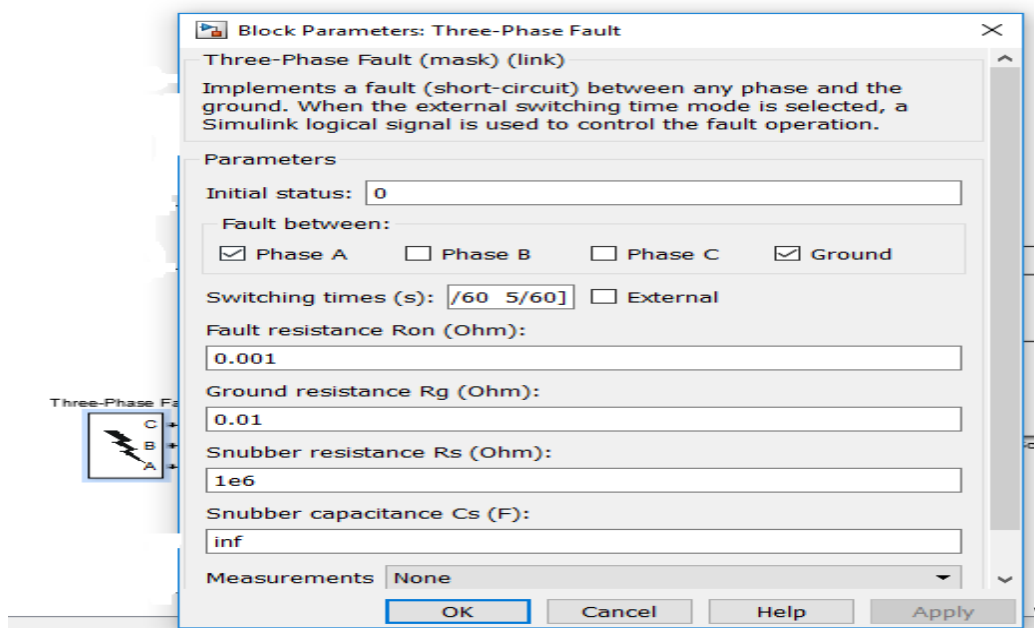


Figure: 5.4 Three-Phase fault Simulink block

5.2.5 Parallel RLC Load Simulink Block

The Three-Phase Parallel RLC Load block implements a three-phase balanced load as a parallel combination of RLC elements. At the specified frequency, the load exhibits a constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

Only elements associated with nonzero powers are displayed in the block icon.

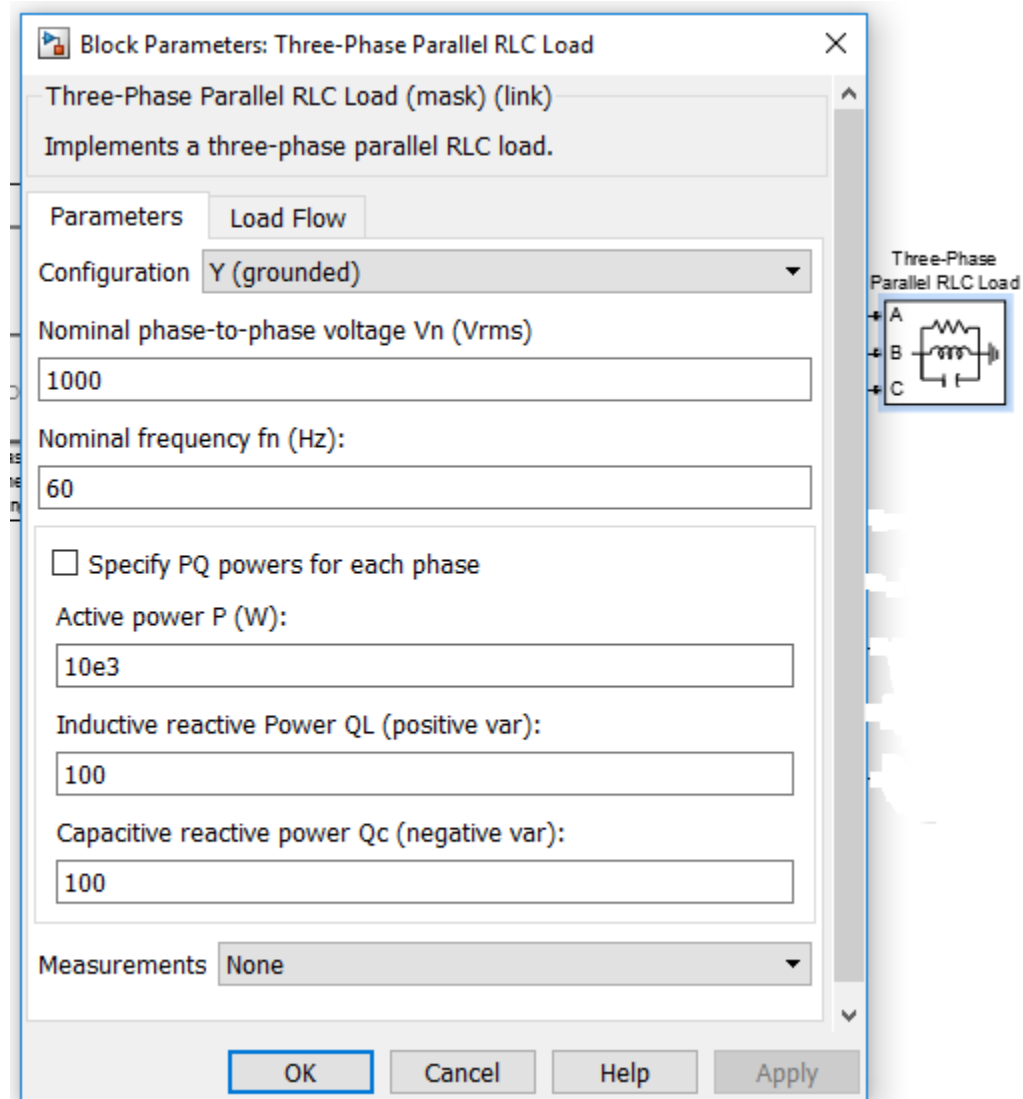


Figure: 5.5 Parallel RLC Load Simulink block

5.2.6 Scope Simulink Block

The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y -axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation.

When you start a simulation, Simulink does not open Scope windows, although it does write data to connected Scopes. As a result, if you open a Scope after a simulation, the Scope's input signal or signals will be displayed.

If the signal is continuous, the Scope produces a point-to-point plot. If the signal is discrete, the Scope produces a stair step plot.

The Scope provides toolbar buttons that enable you to zoom in on displayed data, display all the data input to the Scope, preserve axes settings from one simulation to the next, limit data displayed, and save data to the workspace. The toolbar buttons are labeled in this figure, which shows the Scope window as it appears when you open a Scope block.

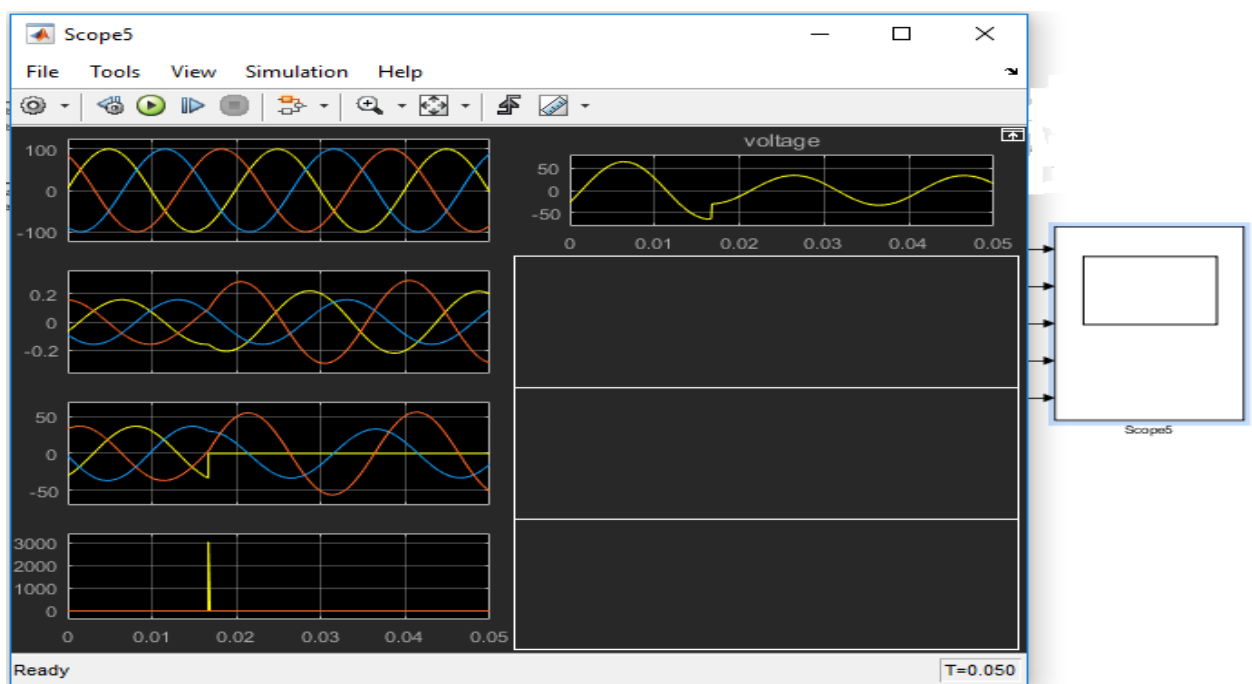


Figure: 5.6 Scope Simulink Block

5.2.7 Powergui Simulink Block

The Powergui block opens a graphical user interface (GUI) that displays steady-state values of measured current and voltages as well as all state variables (inductor currents and capacitor voltages). The Powergui block allows you to modify the initial states in order to start the simulation from any initial conditions.

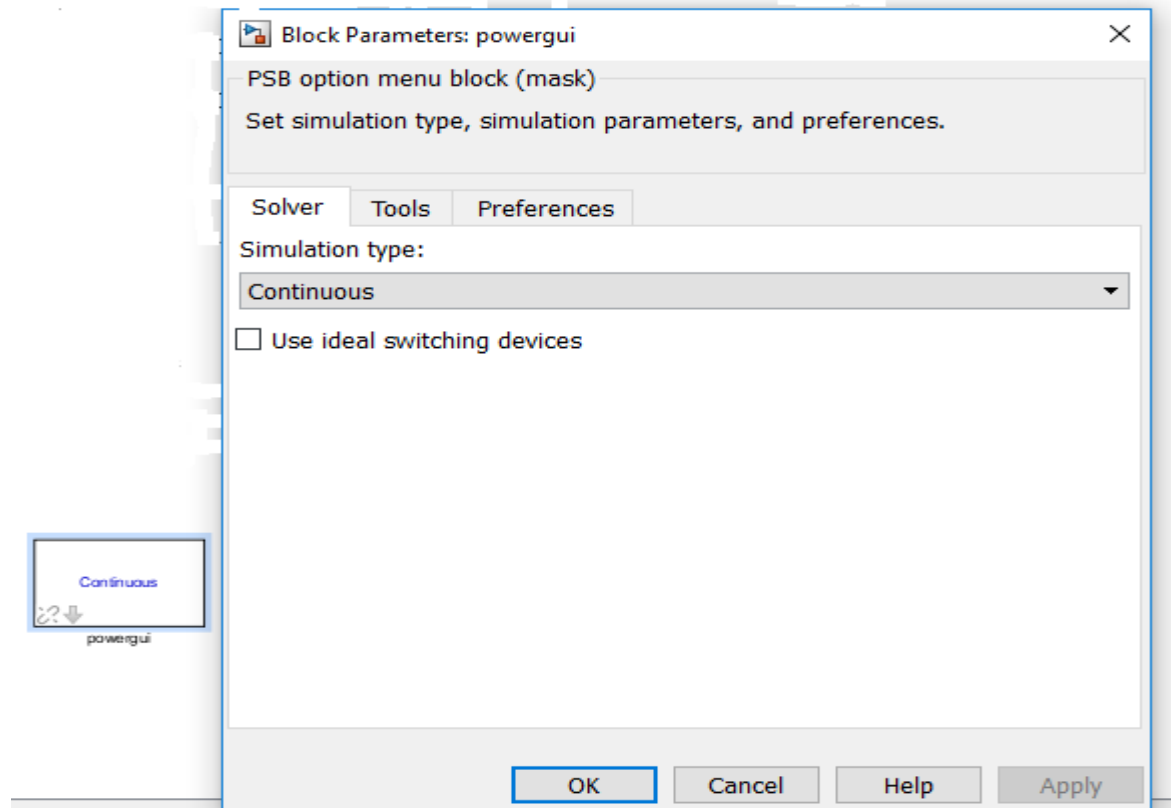


Figure: 5.7 Powergui Simulink Block

5.3 METHODOLOGY

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, certain of user interfaces and interfacing with programs written in other languages. Although MATLAB is intended primarily for numerical computing an optional tool box uses the MuPAD symbolic computing capabilities. An additional package, simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded system. MATLAB users come from various backgrounds of engineering, science and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises. Also MATLAB gives an attractive environment with hundreds of reliable and accurate built-in functions. MATLAB family work together with Simulink software to model electrical, mechanical and control systems. In order to study and analyze the transmission line fault following circuit arrangement are connected to the parameters values

Generator	11kV 3 phase AC voltage source
Load	10KW Active, 100KVar Reactive
Transmission line	Length=300km, R= 0.01273 Ohm/km, L= 0.9337e-3 H/km, C= 12.74e-9 F/km

Figure: 5.1 Parameters of the power system

5.3.1 Circuit Model for Three Phase Faults in Power System Network without Transformer

The implementation deals with the model made in MATLAB using the Sim Power Systems Tool, the GUI. Through this advanced data simulation model fault analysis of any power system network can be simulated with ease and its fault analysis can be carried out.

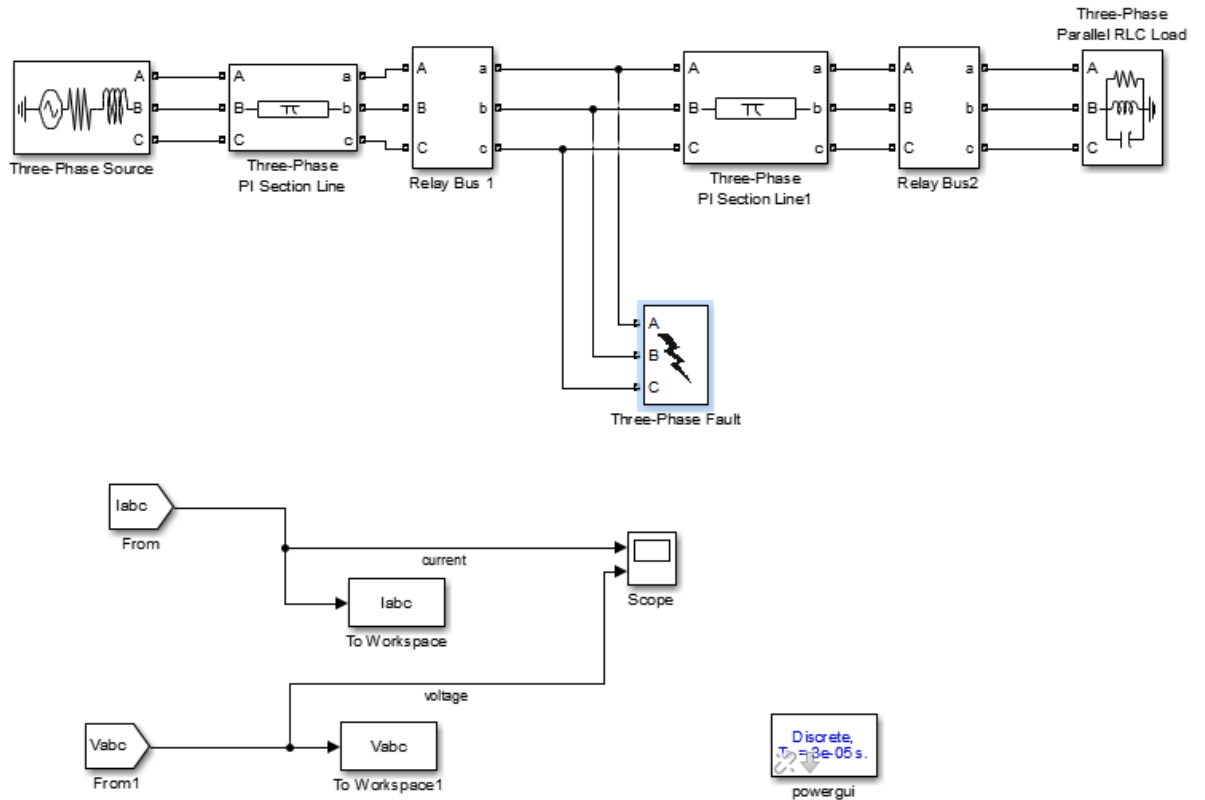


Figure: 5.8 Transmission Line Fault without Transformer

5.3.2 Circuit Model for Three Phase Faults in Power System Network with Transformer

The implementation deals with the model made in MATLAB using the Sim Power Systems Tool, the GUI. Through this advanced data simulation model fault analysis of any power system network can be simulated with ease and its fault analysis can be carried out.

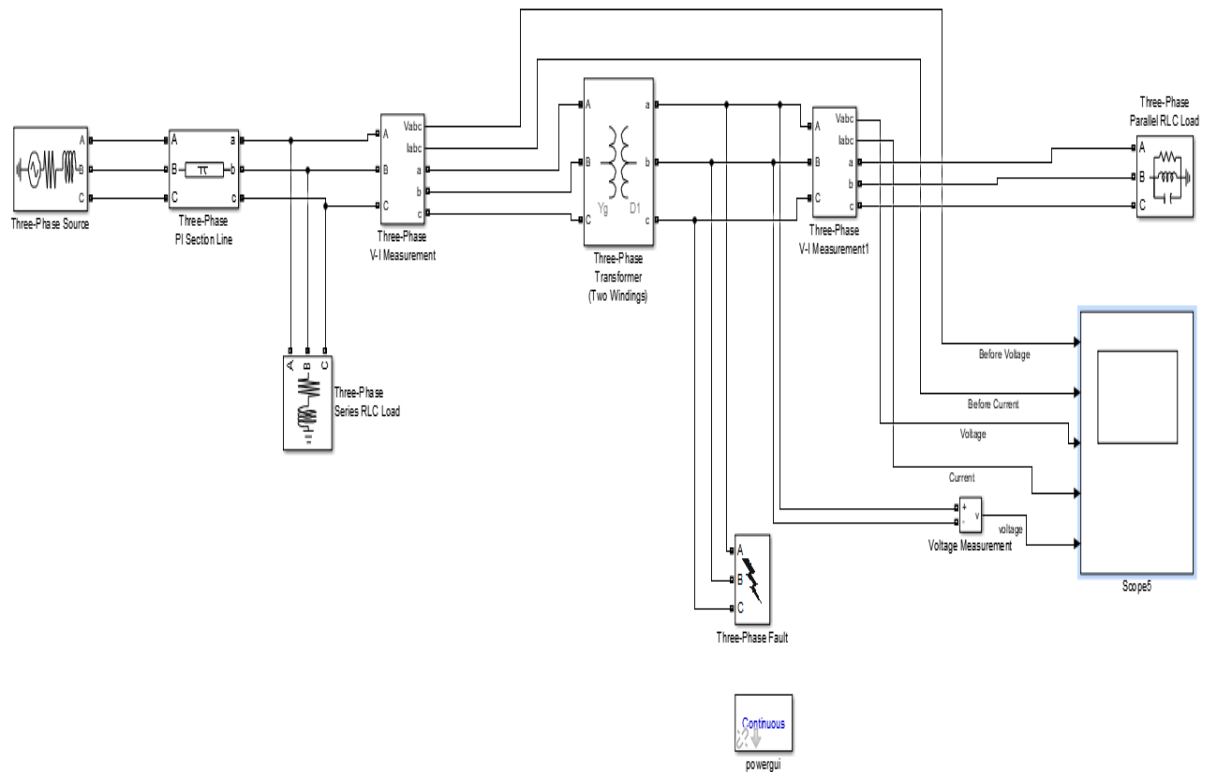


Figure: 5.9 Transmission Line Fault with Transformer

❖ Step By Step Procedure On Development Of Circuit Model

- 1) Start
- 2) Run the model file (.mdl/.slx)
- 3) Define CT & PT Ratio
- 4) Define no. of samples, phases, sampling time (frequency)
- 5) Define fault & circuit breaker operating times
- 6) Define system voltage, & line lengths
- 7) Allocate memory for Current & Voltage data from the three phases
- 8) Check Max & Min values of Current & Voltage in each phase & if $abs(min) > max$, $abs(min) = max$
- 9) Normalize max Current & Voltage value to 32767 & change matrix to array
- 10) Separate phase wise Current & Voltage data into different commands
- 11) Initialize buffer to calculate the trip time
- 12) Create user defined Current & Voltage waveform

- 13) Run Test & get the trip status & trip time of the relay
- 14) Save the generated plots
- 15) Generate report by creating another server for Excel & passing data from MATLAB to Excel
- 16) Convert the file into a pdf & save the report
- 17) End

CHAPTER 6

MATLAB Simulation Result & Discussion

Following are the graph obtained from scope of different type of fault.

6.1 Three Phase To Ground Fault

Now simulation and modeling on three phases to ground fault occurs their three phases is short to the ground. When the magnitude of the faults current line are higher than the normal input current and the voltage are change on the magnitude is zero and the fault the impedance is not necessary zero and output waveform shows the gradually rise of current where three phases to ground fault occur on transmission line.

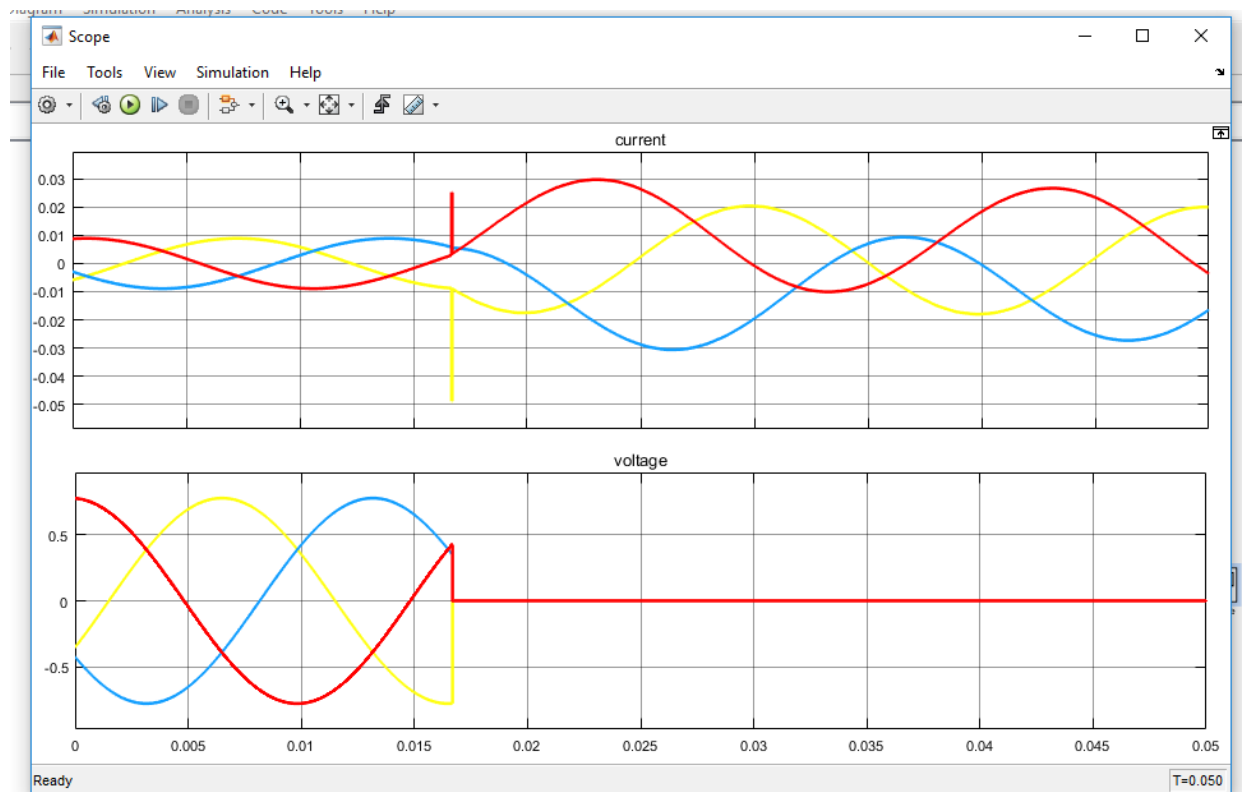


Figure: 6.1 three phase fault current & voltage waveform

In this actual case, the Distribution system model is runs for a Three Phase to Ground Fault. The simulation is done for 0.05 sec, so that the waveforms can be seen more clearly. The sampling frequency is taken to be 50 Hz. The system voltage is taken as 11 kV and the line length is taken as 300 kms, with fault occurring at 150 kms. Fault is started at 0.3 secs. These parameters have been kept constant for other test cases as well. Indicates the current and voltage waveforms for the given specifications. Upon injecting these signals to the relay it has been seen that the relay trips after 45 ms and the status of its coil is shown in the simulated results. As this is a self-reset relay, the trip status comes back to 0 upon clearing the fault, but for a manual reset relay, it stays 1 till the reset button is pressed manually. The proposed matlab model can be ran standalone or on the GUI to view the plots.

6.2 Double Line to Ground Fault

Now simulation and modeling on double line to ground fault occurs their two phases is short to the ground. When the magnitude of the faults current line are higher than the normal input current and the voltage are change on the magnitude is zero and the fault the impedance is not necessary zero and output waveform shows the gradually rise of current where 2L-G fault occur on transmission line.

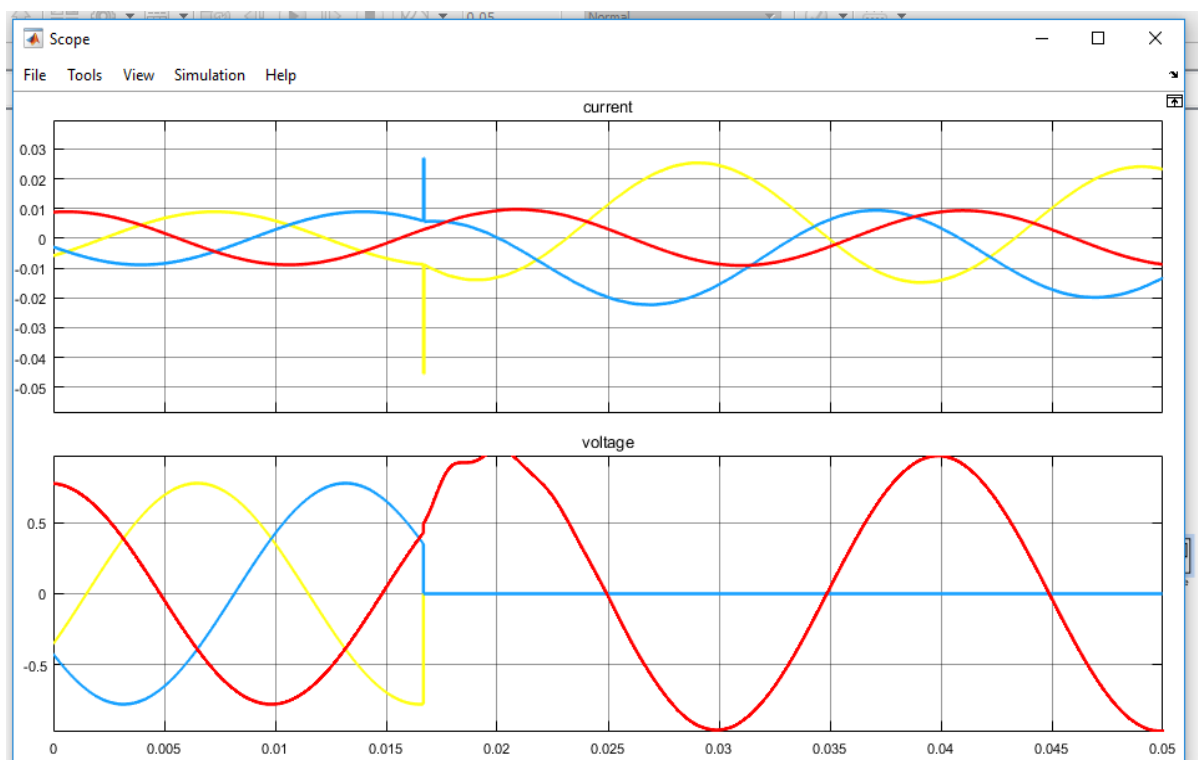


Figure: 6.2 Double Line to Ground Fault current & voltage Waveform from scope

In this actual case, the Distribution system model is runs for a line-line and ground Fault. The simulation is done for 0.05 sec, so that the waveforms can be seen more clearly. The sampling frequency is taken to be 50 Hz. The system voltage is taken as 11 kV and the line length is taken as 300 kms, with fault occurring at 150 kms. Fault is started at 0.3 secs. There are indicates the current and voltage waveforms for the given specifications. Upon injecting these signals to the relay it has been seen that the relay trips after 45 ms and the status of its coil is shown in the simulated results. As this is a self-reset relay, the trip status comes back to 0 upon clearing the fault, but for a manual reset relay, it stays 1 till the reset button is pressed manually. The proposed matlab model can be ran standalone or on the GUI to view the plots.

6.3 Line to Ground FAULT

Here I have simulation and modeling on L-G fault occurs their one phase is short to the ground and the fault the impedance is not zero. When their output waveform shows the rise of current on L-G fault occurs on transmission line.

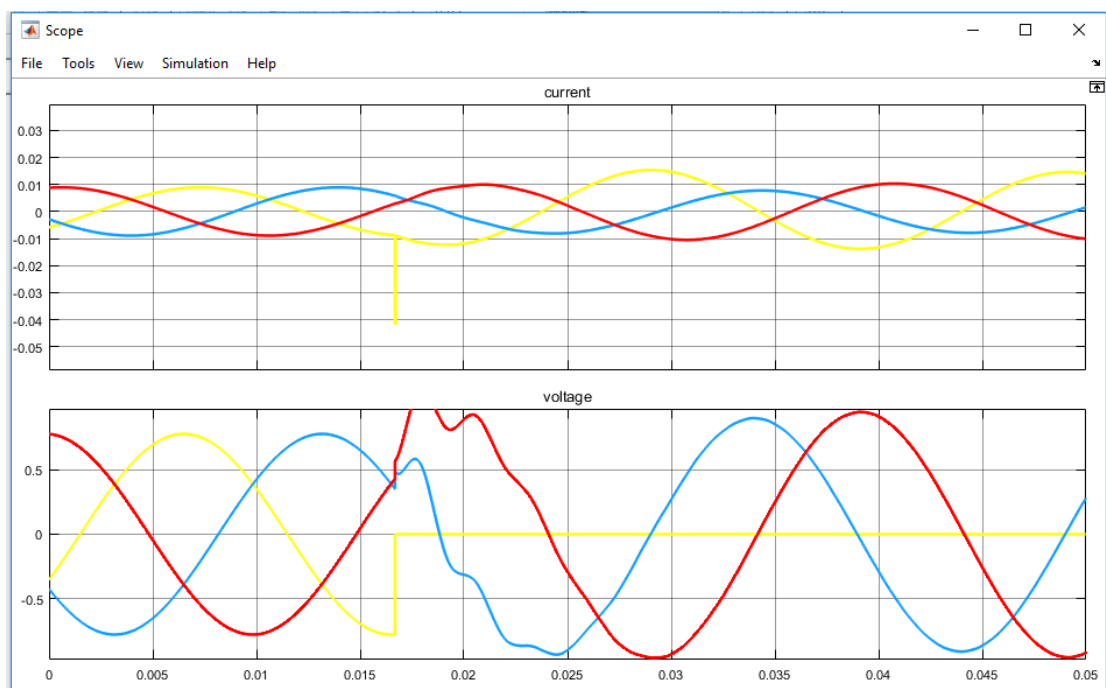


Figure: 6.3 L-G fault Matlab current & voltage Waveform

In this actual case, the Distribution system model is runs for a Line to ground Fault. The simulation is done for 0.05 sec, so that the waveforms can be seen more clearly. The sampling frequency is taken to be 50 Hz. The system voltage is taken as 11kV and the line length is taken as 300 kms, with fault occurring at 150 kms. Fault is

started at 0.3. These parameters have been kept constant for other test cases as well. There are indicates the current and voltage waveforms for the given specifications. Upon injecting these signals to the relay it has been seen that the relay trips after 45 ms and the status of its coil is shown in the simulated results. As this is a self-reset relay, the trip status comes back to 0 upon clearing the fault, but for a manual reset relay, it stays 1 till the reset button is pressed manually. The proposed matlab model can be ran standalone or on the GUI to view the plots.

6.4 Three Phase To Ground Fault with Transformer

Now simulation and modeling on three phases to ground fault occurs their three phases is short to the ground. When the magnitude of the faults current line are higher than the normal input current and the voltage are change on the magnitude is zero and the fault the impedance is not necessary zero and output waveform shows the gradually rise of current where three phases to ground fault occur on transmission line. I see the same occurs in the transmission lines connected to transformer and with to transformer.

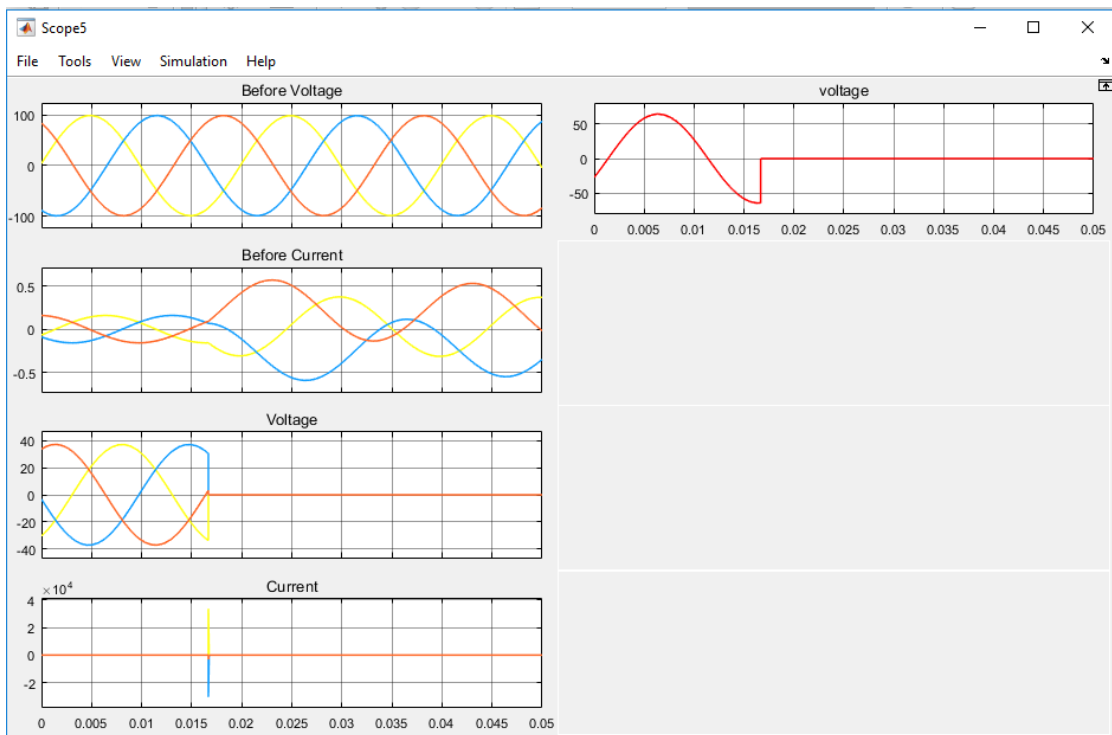


Figure: 6.4 Three phase to ground fault

In this actual case, the Distribution system model is runs for a three phase to ground fault. The simulation is done for 0.05 sec, so that the waveforms can be seen more clearly. The sampling frequency is taken to be 50 Hz. The system voltage is taken as 11kV and the line length is taken as 300 kms, with fault occurring at 150 kms. Fault is started at 0.3. These parameters have been kept constant for other test cases as well. There are indicates the current and voltage waveforms for the given specifications. Upon injecting these signals to the relay it has been seen that the relay trips after 45 ms and the status of its coil is shown in the simulated results. As this is a self-reset relay, the trip status comes back to 0 upon clearing the fault, but for a manual reset relay, it stays 1 till the reset button is pressed manually. The proposed matlab model can be ran standalone or on the GUI to view the plots.

6.5 Double Line To Ground Fault

Now simulation and modeling on double line to ground fault occurs their two phases is short to the ground. When the magnitude of the faults current line are higher than the normal input current and the voltage are not change on magnitude and the fault the impedance is not necessary zero and output waveform shows the gradually rise of current where 2L-G fault occur on transmission line. I see the same occurs in the transmission lines connected to transformer and with to transformer.

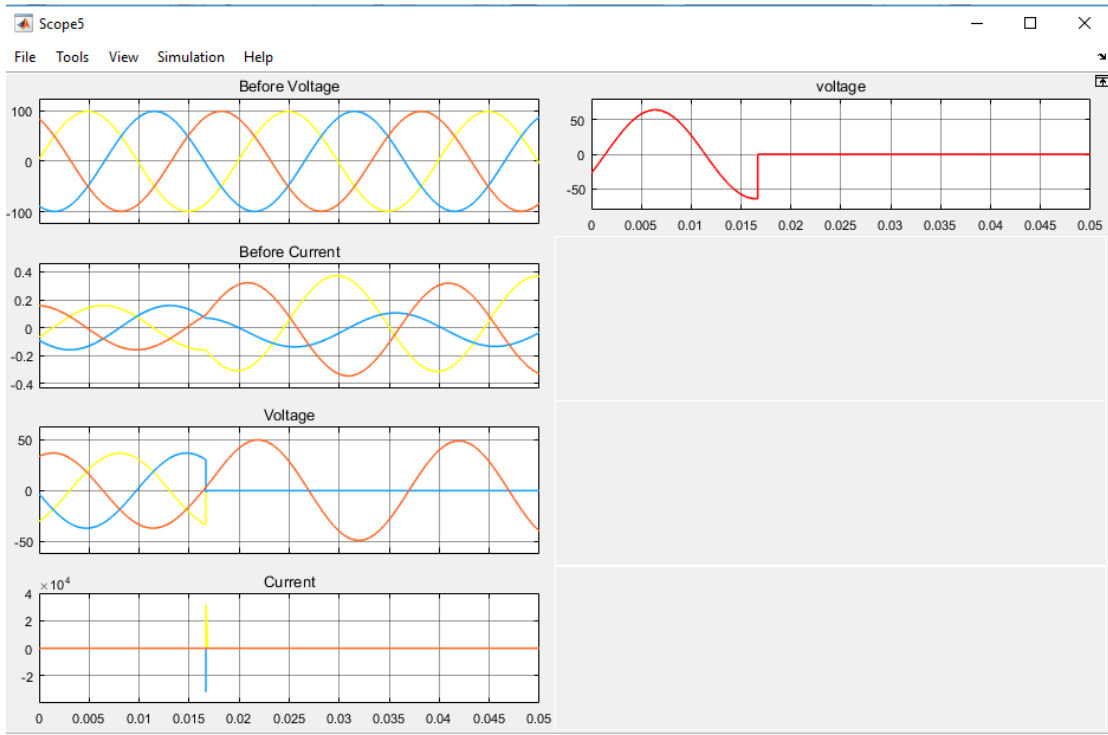


Figure: 6.5 Line-Line-ground Fault

In this actual case, the Distribution system model is runs for a Line-Line-ground Fault. The simulation is done for 0.05 sec, so that the waveforms can be seen more clearly. The sampling frequency is taken to be 50 Hz. The system voltage is taken as 11kV and the line length is taken as 300 kms, with fault occurring at 150 kms. Fault is started at 0.3. These parameters have been kept constant for other test cases as well. There are indicates the current and voltage waveforms for the given specifications. Upon injecting these signals to the relay it has been seen that the relay trips after 45 ms and the status of its coil is shown in the simulated results. As this is a self-reset relay, the trip status comes back to 0 upon clearing the fault, but for a manual reset relay, it stays 1 till the reset button is pressed manually. The proposed matlab model can be ran standalone or on the GUI to view the plots.

6.6 L-G FAUL

Here I have simulation and modeling on L-G fault occurs their one phase is short to the ground and the fault the impedance is not zero. When their output waveform shows the rise of current on L-G fault occurs on transmission line. I see the same occurs in the transmission lines connected to transformer and without to transformer.

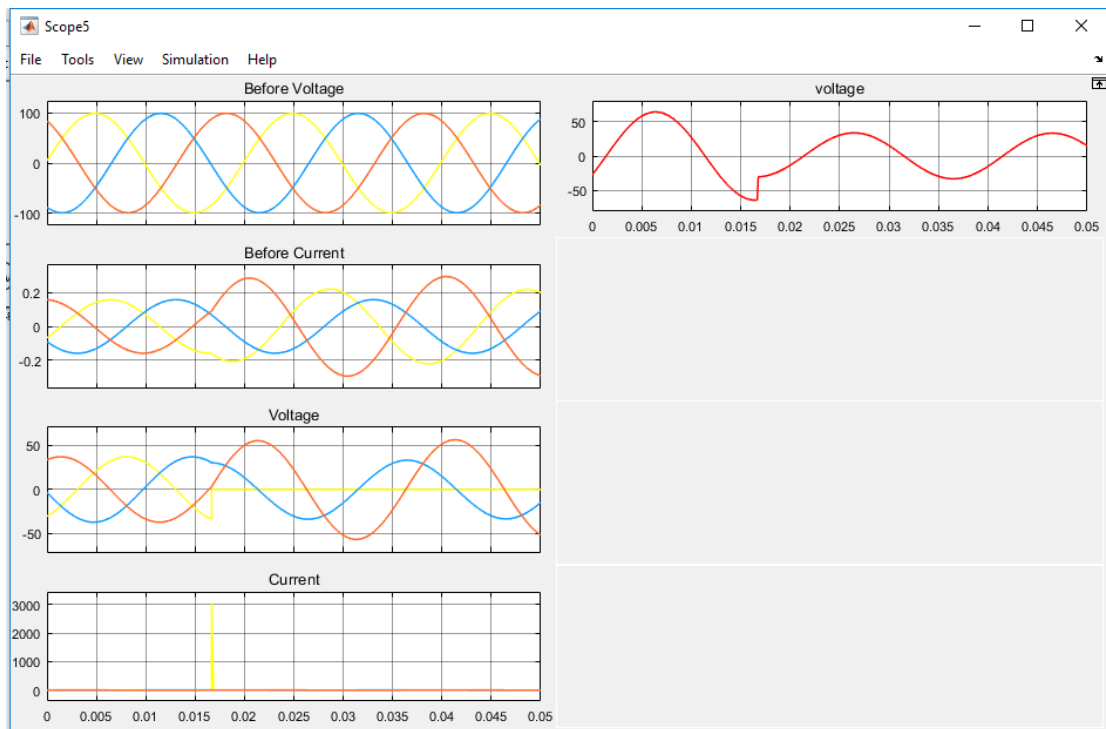
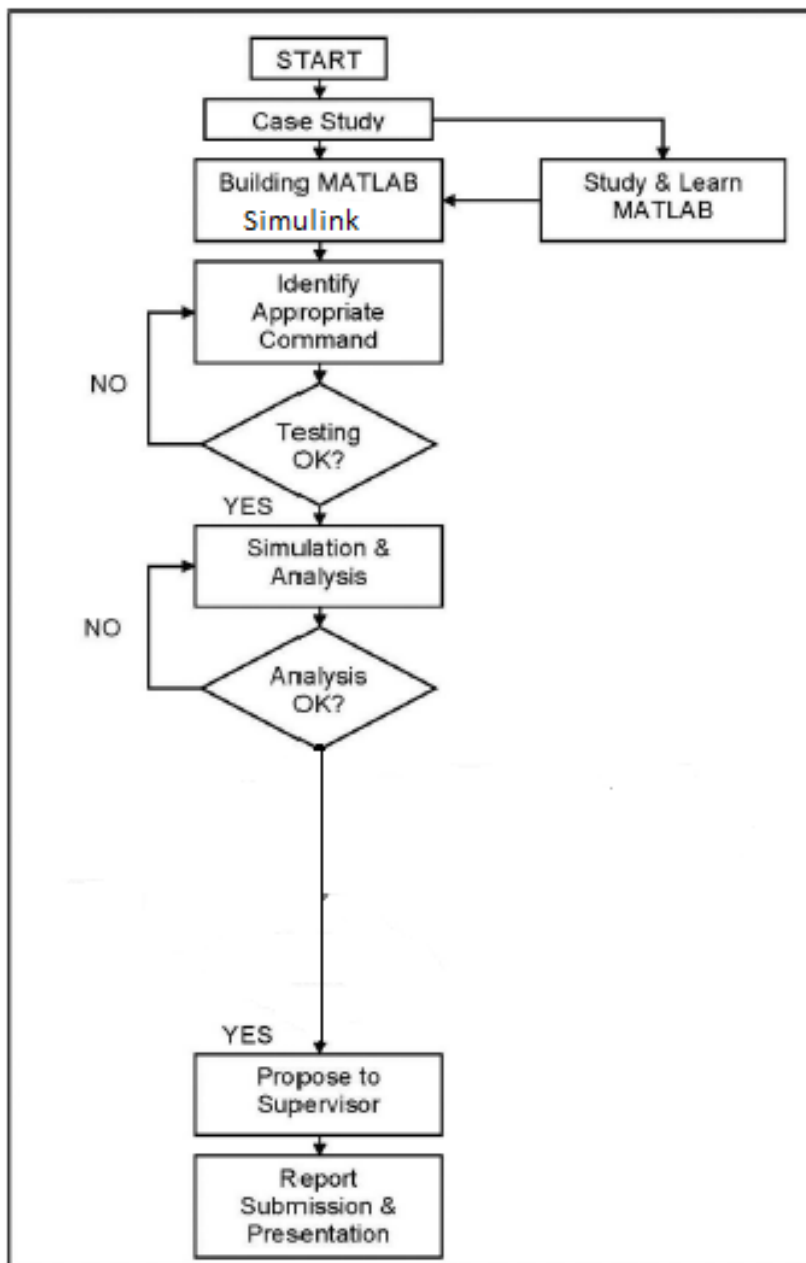


Figure: 6.6 L-G FAULT

In this actual case, the Distribution system model is runs for a L-G FAULT. The simulation is done for 0.05 sec, so that the waveforms can be seen more clearly. The sampling frequency is taken to be 50 Hz. The system voltage is taken as 11kV and the line length is taken as 300 kms, with fault occurring at 150 kms. Fault is started at 0.3. These parameters have been kept constant for other test cases as well. There are indicates the current and voltage waveforms for the given specifications. Upon injecting these signals to the relay it has been seen that the relay trips after 45 ms and the status of its coil is shown in the simulated results. As this is a self-reset relay, the trip status comes back to 0 upon clearing the fault, but for a manual reset relay, it stays 1 till the reset button is pressed manually. The proposed matlab model can be ran standalone or on the GUI to view the plots.

6.7 Working Flow Chart



CHAPTER 7

Conclusions

7.1 Conclusion

The simulation and analysis of three phase fault to achieve results of the transmission line parameter is convenient by using MATLAB software. In this paper simulation of three phase transmission line fault analysis system is proposed. Single Line to Ground fault, Double Line fault etc in transmission line is also simulated. This system opens the way to redesign the bus system of the power system according to its results. The proposed work can able to implement for a larger power systems geographically apart.

7.2 Limitations of the Work

Mention few limitations or challenges faced in my work. In this thesis, i have faced few problems as like as.

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