“ANALYSIS AND DESIGN OF DISTANCE PROTECTION SCHEME”

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

(Electrical Power Systems)

By

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I, **Mehta Gaurang Mahendrabhai** , Roll No.**12MEEE19**, give undertaking that the Major Project entitled **"Analysis and Design of Distance Protection Scheme"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Electrical Power Systems** of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Certificate

This is to certify that the Major Project Report entitled **"Analysis and Design of Distance Protection Scheme"** submitted by **Mr. Gaurang M. Mehta (12MEEE19)** towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

Maloperation of over-current relays for low voltage system can be tolerated as the supply to consumers has to be supplied continuously but cannot be tolerated for EHV system. Distance protection, or distance relay, is a type of protection system which detects fault within pre-set zone of transmission lines and hence enabling the necessary actions to isolate the faulted lines. This device is required to provide reliability in the protection system of transmission lines, avoiding loss of load or loss of synchronism in case of disturbances. The operation of distance relays is influenced by different factors such as **mutual compensation**, **load encroachments**, **power swings** etc.; hence affecting its performance. To ensure its reliable operation, various settings parameters will be studied and recommendations will be provided based on the analysis and calculations.Here, analysis on the different types and make of Distance Protective Relays will be done, e.g. MiCOM P441,442,444, REL 670. Based on that analysis and calculations, software based modeling will be done for different characteristics for Distance Relays. Operation of relay during power swing will be studied and its operation will be analysed.

ABBREVIATIONS

CT .... Current Transformer

PT .... Potential Transformer

ICT .... Interconnecting Transformer

CCVT .... Capacitance-coupled Voltage Transformer

K_{Z0} .... Residual Compensation Factor

$\angle K_{Z0}$ .... Residual Compensation Factor Angle

RFPP .... Resistive Reach for Phase-Phase Faults(REL 670)

RFPE .... Resistive Reach for Phase-Earth Faults(REL 670)

NOMENCLATURE

Total Line Impedance .... Z_L

Zone-1 Impedance Reach .... Z_1

Zone-2 Impedance Reach .... Z_2

Zone-3 Impedance Reach .... Z_3

Zone-4 Impedance Reach .... Z_4

Maximum Load Current .... R_L

Phase-Neutral Voltage (Secondary) .... V_N

Secondary Current .... I_N

Zero Sequence Impedance of the Line .... Z_{L0}

Positive Sequence Impedance of the Line .... Z_{L1}

Time Delay for Zone-1 .... T_{Z1}

Time Delay for Zone-2 .... T_{Z2}

Time Delay for Zone-3 .... T_{Z3}

Time Delay for Zone-4 .... T_{Z4}

Maximum Resistive Reach for Phase Faults .... $R_{Ph}(Max)$

Maximum Resistive Reach for Ground Faults .... $R_G(Max)$

Warrington's Worst Case Formula Arc Resistance .... R_a

Maximum Phase Conductor Spacing L

Minimum Expected Phase-Phase Fault Current .... I_{arc}

Minimum Resistive Reach for Phase Faults .... $R_{Ph}(Min)$

Minimum Resistive Reach for Ground Faults .... $R_G(Min)$

Resistive Reach for Phase-Phase Faults for Zone-1 .... R_{1Ph}

Resistive Reach for Phase-Phase Faults for Zone-2 .... R_{2Ph}

Resistive Reach for Phase-Phase Faults for Zone-3&4 .... $R_{3Ph} - R_{4Ph}$

Resistive Reach for Phase-Ground Faults for Zone-1 .... R_{1G}

Resistive Reach for Phase-Ground Faults for Zone-2 .... R_{2G}

Resistive Reach for Phase-Ground Faults for Zone-3&4 .... $R_{3G} - R_{4G}$

Width of the Power Swing Detection Band .... ΔR , ΔX

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Chapter 1

Introduction

Power system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network.

The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic and pessimistic approach to clearing system faults.

1.1 Protection systems usually comprise five components:

a. Current and voltage transformers to step down the high voltages and currents of the electrical power system to convenient levels for the relays to deal with;

b. Protective relays to sense the fault and initiate a trip, or disconnection, order;

c. Circuit breakers to open/close the system based on relay and autorecloser commands;

d. Batteries to provide power in case of power disconnection in the system.

e. Communication channels to allow analysis of current and voltage at remote terminals of a line and to allow remote tripping of equipment.

1.2 Protection System

There are many type of Protection schemes;here focus will be on Distance Protection Scheme. Distance Protection is a widely used protective scheme for the protection of high and extra high voltage transmission and sub-transmission lines. This scheme employs a number of distance relays which measure the impedance or some components of the line impedance at the relay location.[7] The measured quantity is proportional to the line-length between the location of the relay and the point where the fault has occurred. As the measured quantity is proportional to the distance along the line, the measuring relay is called a distance relay.

The most important and versatile family of relays is the distance-relay group. It includes the following types:

a. **Impedance relays,**

b. **Reactance relays,**

c. **MHO relays,**

d. **Angle impedance relays,**

e. **Quadrilateral relays,**

f. **Elliptical and other conic section relays.**

1.3 Thesis Organization

The thesis is divided into following chapters.

- **Chapter-2**
  This chapter contains basic theory about Distance Protection, its zone-wise characteristics, different type of distance relays, its tripping characteristics and actual system.

- **Chapter-3**
  In this chapter, the data of the main protected line and the adjacent lines has been given along with the CT and CCVT details. For the existing line, the calculation for distance protection has been done. The importance of Residual compensation factor is discussed and its use is mentioned.The calculations has been done for both MiCOM P444 relay and REL 670.

- **Chapter-4**
  In this chapter, the modelling part which has been developed using PSCAD/EMTDC software has been discussed in step by step. The system then has been simulated for MHO characteristics and Quadrilateral Characteristics. The effect of fault resistance on the operation of distance protection scheme has been discussed as well.

- **Chapter-5**
  In this chapter, the effect of power swing on distance protection has been discussed. Here, the calculation is performed as per given in Network Protection and Automation Guide. The system is simulated for different faults and it can be seen that the relay does not get tripped during power swings.

1.4 Literature Survey

- **Micom P441, P442, P444 - Technical Manual:**
  This technical manual gives the method by which calculation can be done for different zones and also gives significance of the residual compensation factor. MiCOM is numerical relay by Alstom.It is a six zone Distance Relay; having many other protective functions as well. Even it works well during Power Swings.

- **REL 670 - Technical Manual:**
  This technical manual gives the idea of calculating different zones reach and also gives significance of the importance of REL 670 relay.It is numerical relay by ABB.It is a six zone Distance Relay; having many other protective functions as well. Even it works well during Power Swings.

- **Simulation of MHO characteristics for transmission line protection using PSCAD: Yashvi B, Vidushi K and Ramesh P:**
  In this paper, authors have shown how mho characteristics can be realised using PSCAD for transmission line protection. They have simulated the 200km long, 230kv line for three zone of protection. Also, they have discussed the effect of fault resistance on the mho relay along with the simulation.

- **Performance of Quadrilateral Relay on EHV transmission line protection during various faults: Harikrishna M:**
  In this paper, author has shown the performance of Quadrilateral Relay for different types of Faults. Modelling and simulation has been done using PSCAD (EMTDC) analysis software and the results has been obtained. Also, algorithm has been given along with the setting parameters. Author has simulated for two-zone protection.

- **Numerical Quadrilateral Distance Relay: Tushar Yesansure:**
  This paper presents a new technique for implementation of numerical quadrilat-

eral relay. Here, the characteristics is realized by measuring the instantaneous values of the voltage and current based on sampling principle.This paper also presents the Algorithm and Program Flowchart for the Quadrilateral Relay.

- **Method for setting the Resistive Reach of Quadrilateral Characteristics of Distance Relays: Elmer Sorrentino, Eliana Rojas, Jesus Hernandez:**
  In this paper, new method for setting the resistive reach on quadrilateral characteristics of distance relays is proposed. The method presented is based on analysis of the impedance seen by the relay(apparent impedances); also, here the resistive reach setting is calculated assuming that the reactive reach setting has been previously defined.

Chapter 2

Distance Relays

2.1 Basic Principle

A distance relay, as its name implies, has the ability to detect a fault within a pre-set distance along a transmission line or power cable from its location. Every power line has a resistance and reactive per kilometer related to its design and construction so its total impedance will be a function of its length or distance. A distance relay therefore looks at current and voltage and compares these two quantities on the basis of Ohms law[6].

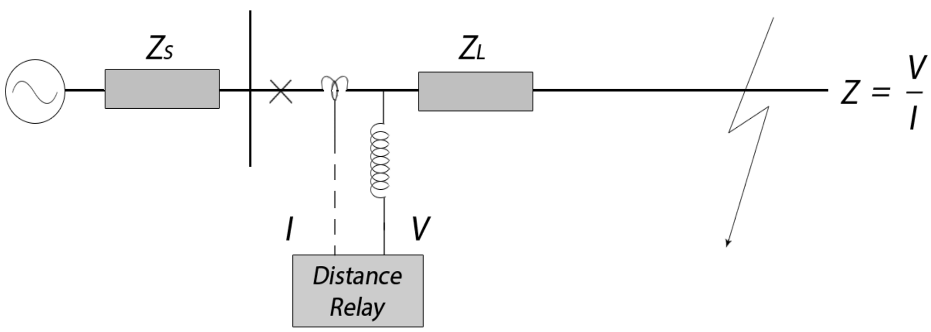

Figure 2.1: Basic Principle of operation

2.2 Tripping Characteristics

If the relays operating boundary is plotted, on an R-X diagram, its impedance characteristic is a circle with its center at the origin of the coordinates and its radius will be the setting (reach) in ohms.

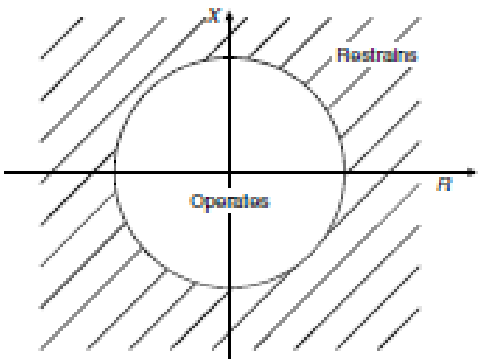

Figure 2.2: Plain Impedance Characteristics

The relay will operate for all values less than its setting i.e. is for all points within the circle.

This is known as a plain impedance relay and it will be noted that it is non-directional, in that it can operate for faults behind the relaying point. It takes no account of the phase angle between voltage and current.

Additional voltages are fed into the comparator in order to compare the relative phase angles of voltage and current, so providing a directional feature. This has the effect of moving the circle such that the circumference of the circle now passes through the origin. Angle θ is known as the relays characteristic angle.

This is known as the MHO relay, so called as it appears as a straight line on an admittance diagram. By the use of a further technique of feeding in voltages from the healthy phases into the comparator (known as cross polarization) a reverse movement or offset of the characteristic can be obtained (see Figure 2.4). This is called the offset MHO characteristic.

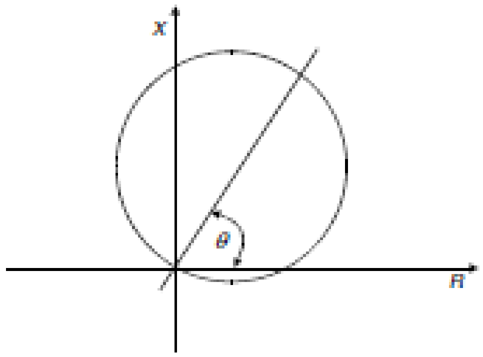

Figure 2.3: MHO characteristics

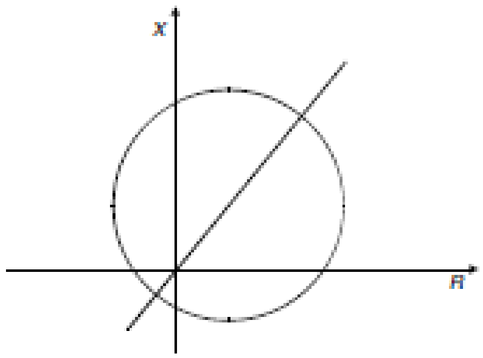

Figure 2.4: Offset MHO characteristics

2.3 Zone wise settings

2.3.1 Zone-1 setting

The zone-1 elements of a distance relay should be set to cover as much of the protected line as possible, allowing instantaneous tripping for as many faults as possible. In most applications the zone-1 reach (Z1) should not be able to respond to faults beyond the protected line. For an under-reaching application the zone-1 reach must therefore be set to account for any possible overreaching errors. These errors come from the relay, the VTs and CTs and inaccurate line impedance data. It is therefore recommended that the reach of the zone-1 distance elements is restricted to 80-85% of the protected line impedance (positive phase sequence line impedance).[2]

2.3.2 Zone-2 setting

The zone-2 elements should be set to cover the 20% of the line not covered by zone-1. Allowing for under-reaching errors, the zone-2 reach (Z2) should be set in excess of 120% of the protected line impedance for all fault conditions. Where aided tripping schemes are used, fast operation of the zone-2 elements is required. It is therefore beneficial to set zone-2 to reach as far as possible, such that faults on the protected line are well within reach. A constraining requirement is that, where possible, zone-2 does not reach beyond the zone-1 reach of adjacent line protection. Where this is not possible, it is necessary to time grade zone-2 elements of relays on adjacent lines. For this reason the zone-2 reach should be set to cover $\leq$50% of the shortest adjacent line impedance, if possible.[2]

2.3.3 Zone-3 setting

The zone-3 elements would usually be used to provide overall back-up protection for adjacent circuits. The zone-3 reach (Z3) is therefore set to approximately 120% of the combined impedance of the protected line plus the longest adjacent line. A higher apparent impedance of the adjacent line may need to be allowed where fault current can be fed from multiple sources or flow via parallel paths.[2]

2.3.4 Zone-4 setting

The zone-4 elements would typically provide back-up protection for the local busbar, where the offset reach is set to 25% of the zone-1 reach of the relay for short lines (less than 30km) or 10% of the zone 1 reach for long lines.[2]

2.4 Quadrilateral characteristics

Modern Distance Relays uses Quadrilateral characteristics. The system which will be considered for study has MiCOM P441,P442,P444 Relay which possesses quadrilateral characteristics with six zones of protection. Main difference is of the shape of the characteristics only otherwise the operation remains the same.

This form of polygonal impedance characteristic is shown in Figure 2.5. The characteristic is provided with forward reach and resistive reach settings that are independently adjustable. It therefore provides better resistive coverage than any MHO-type characteristic or short lines. This is especially true for earth fault impedance measurement, where the arc resistances and fault resistance to earth contribute to the highest values of fault resistance. To avoid excessive errors in the zone reach accuracy, it is common to impose a maximum resistive reach in terms of the zone impedance reach. Recommendations in this respect can usually be found in the appropriate relay manuals.

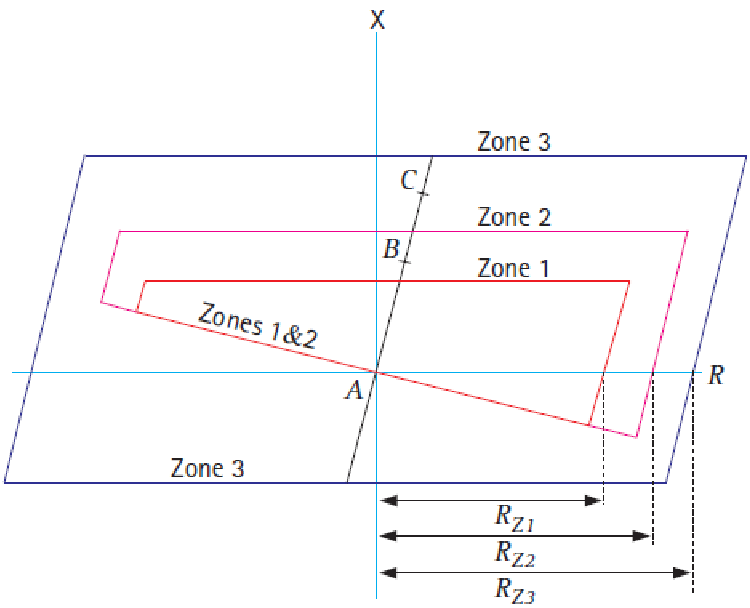

Figure 2.5: Quadrilateral characteristics

2.5 Actual System

The actual system which is considered for the study case is the line from Rajpure TPPS to Nakodar, which is 4ookV, 139km long transmission line. The line adjacent to the main protected line is the Nakodar to Makhu; which is 53km long. The calculations and the system which will be simulated will be of the main protected line. First the Distance Protection will be simulated using MHO Characteristics and then the same system will be simulated using Quadrilateral Characteristics. Along with this, Power Swing calculations and its simulation will be shown.

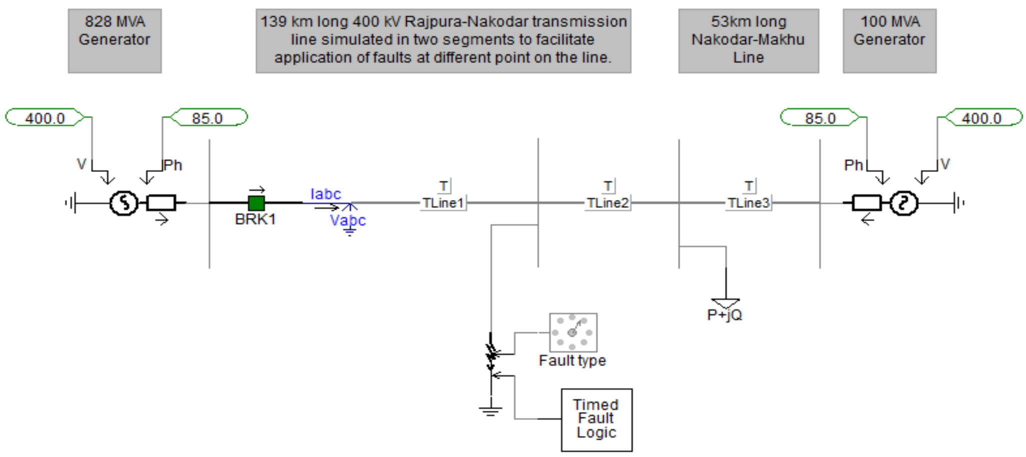

Figure 2.6: Main System

As shown in the above figure 2.6, there are three lines shown. To facilitate fault conditions, main line is segmented into two parts. The simulation is carried out using PSCAD/EMTDC software.

Generator-1 has rating 0f 828 MVA and Generator-2 has 100 MVA. The load is assumed to be 20 MW + j18 MVAR.

Chapter 3

Data and Calculations

Rajpura to Nakodar is a 139 km long transmission line whose distance protection has been done. Adjacent to it is the Nakodar to Makhu line which is 53km long.

Table I: Details of main protected line **(Rajpura TPPS-Nakodar)**

Sr. No.	Parameter	Unit	Value
1 1	Relay Type	-	MiCOM P444
2	Length of Protected Line	Km	139
3	Positive Sequence Resistance	Ω/km	0.02897
4	Positive Sequence Reactance	Ω/km	0.3072
5	Positive Sequence Impedance	Ω/km	0.309
6	Positive Sequence Resistance	Ω	4.0268
7	Positive Sequence Reactance	Ω	42.701
8	Positive Sequence Impedance	Ω	42.890
9	Positive Sequence Impedance angle	◦	84.613
10	Zero Sequence Resistance	Ω/km	0.2569
11	Zero Sequence Reactance	Ω/km	1.0223
12	Zero Sequence Impedance	Ω/km	1.054
13	Zero Sequence Resistance	Ω	35.719
14	Zero Sequence Reactance	Ω	142.100
15	Zero Sequence Impedance	Ω	146.520
16	Zero Sequence Impedance angle	◦	75.891

3.1 MiCOM P444

MiCOM P441 P442 P444 is the relay which is installed there.So, its study is necessary. The system study for line protection has been simulated using PSCAD (EMTDC). First, it has been done using MHO characteristics and then it has been done using Quadrilateral characteristics. The tables shown below are the line data details for Rajpura TPPS - Nakodar line , Nakodar - Makhu line,ICT Details at Nakodar end and CT and CCVT data.The first table shows the details of the main protected line which is from Rajpura TPPS to Nakodar line. The second table is for the adjacent shortest line which is from Nakodar to Makhu. The third table shows the details for ICT and the fourth table is the CT and PT details.[2]

Table II: Details of adjacent shortest line **(Nakodar-Makhu)**

Sr. No.	Parameter	Unit	Value
1	Length of the Line	Km	53
2	Positive Sequence Resistance	Ω/km	0.02897
3	Positive Sequence Reactance	Ω/km	0.3072
4	Positive Sequence Impedance	Ω/km	0.3085
5	Positive Sequence Resistance	Ω	1.535
6	Positive Sequence Reactance	Ω	16.285
7	Positive Sequence Impedance	Ω	16.357
8	Positive Sequence Impedance angle	◦	84.613
9	Zero Sequence Resistance	Ω/km	0.2569
10	Zero Sequence Reactance	Ω/km	1.0223

Table III: ICT Details at Nakodar

Sr. No.	Parameter	Unit	Value
1	ICT Impedance	%	12.5
2	ICT Rating	MVA	315
3	Voltage Rating	kV	400
4	Impedance of One ICT in circuit	Ω	63.492
5	Impedance of Two ICT in circuit	Ω	31.746

Table IV: CT & PT Details

Sr. No.	Parameter	Unit	Value
1	CT Primary	A	2000
2	CT Secondary	A	1
3	PT Primary	kV	230.940
4	PT Secondary	V	63.509
5	Ratio CT/VT	-	0.55

3.2 Calculations

The calculations for the Distance Protection for the given protected line is as shown below:

3.2.1 System Data

Line length : 139km

Line Impedance :

Z1=0.02897+j0.30720 Ω/km

Z0=0.25697+j1.02230 Ω/km

CT Ratio : 2000/1

PT Ratio : 400000/110

3.2.2 Line Impedance

$$
\begin{aligned}
Ratio\ of\ Secondary\ to\ Primary\ Impedance &= \frac{CT Ratio}{PT Ratio} \\
&= \frac{\frac{2000}{1}}{\frac{400000}{110}} \\
&= 0.55 \qquad (3.1)
\end{aligned}
$$

$$\begin{aligned} Total\ Line\ Impedance, Z_L &= 42.8866\angle 84.613^\circ \\ &= 23.5873\angle 84.613^\circ \end{aligned} \tag{3.2}$$

3.2.3 Zone Impedance Reach

$$\begin{aligned} Required\ Zone-1\ Reach &= 0.8 * Total\ line\ Impedance * \frac{CTRatio}{PTRatio} \\ &= (0.8) * 42.8866\angle 84.613^\circ * (0.55) \\ &= 18.87\angle 84.613^\circ \end{aligned} \tag{3.3}$$

$$\begin{aligned} Required\ Zone-2\ Reach &= Z_L + (0.25 * ParallelICT\ Impedance) * \frac{CTRatio}{PTRatio} \\ &= 27.953\angle 84.613^\circ \end{aligned} \tag{3.4}$$

$$\begin{aligned} Required\ Zone-3\ Reach &= Z_L + 0.5 * (ParallelICT\ Impedance) * \frac{CTRatio}{PTRatio} \\ &= 32.318\angle 84.613^\circ \end{aligned} \tag{3.5}$$

$$\begin{aligned} Required\ Zone-4\ Reach &= 0.1 * (Zone-1\ Reach) \\ &= 1.878\angle 84.613^\circ \end{aligned} \tag{3.6}$$

3.2.4 Residual Compensation for Earth Fault Elements

The residual compensation factor can be applied independently to certain zones if required. This feature is useful where line impedance characteristics change between sections or where hybrid circuits are used. In this example, the line impedance characteristics do not change and as such a common k_{Z0} factor can be applied to each zone. This is set as a ratio k_{Z0}, and an angle $\angle K_{Z0}$[3].

$$\begin{aligned} kZ0\ Res.\ Comp,\ |k_{Z0}| &= \frac{Z_0 - Z_1}{Z_1} \\ &= 0.811 \end{aligned} \tag{3.7}$$

$$\begin{aligned} kZ0\ Angle,\ \angle k_{Z0} &= \angle \frac{Z_0 - Z_1}{Z_1} \\ &= -12.36^\circ \end{aligned} \tag{3.8}$$

For our case, Residual Compensation Factor for all the zones remains same, i.e., k_{Z0}, k_{Z1}, k_{Z2}, k_{Z3} remains equal to $0.811\angle{-12.36^\circ}$.

3.3 Resistive Reach Calculations

All distance elements must avoid the heaviest system loading. Taking the 1A CT secondary rating as a guide to the maximum load current, the minimum load impedance presented to the relay would be:

$$\begin{aligned} V_{N(P-N)}/I_N &= \frac{110 \div \sqrt{3}}{1} \\ &= 63.509\Omega\ (Secondary) \end{aligned} \tag{3.9}$$

Typically, phase fault distance zones would avoid the minimum load impedance by a margin of $\geq 40\%$ if possible bearing in mind that the power swing characteristic surrounds the tripping zones, earth fault zones would use a $\geq 20\%$ margin.

$$\begin{aligned} Maximum\ reach\ for\ Phase\ faults\ (R_{Ph}) &= 0.6 * R_L \\ &= (0.6) * 63.509 \end{aligned}$$

$$= 38.1054\Omega\,(Secondary) \quad (3.10)$$

$$\begin{aligned} Maximum\,reach\,for\,Earth\,faults\,(R_G) &= 0.8 * R_L \\ &= (0.8) * 63.509 \\ &= 50.8072\Omega\,(Secondary) \quad (3.11) \end{aligned}$$

3.4 Warrington's worst case formula

Using the empirical formula derived by A.R. van C. Warrington, the approximate value of arc resistance can be assessed as:[3]

$$\begin{aligned} R_a &= \frac{28710 * (L)}{I_{arc}^{1.4}} \\ &= \frac{28710 * (7)}{2000^{1.4}} \\ &= 4.8049\Omega \quad (3.12) \end{aligned}$$

where:

R_a = arc resistance (ohms)

L = length of the arc (metres)

I_{arc} = arc current (A)

On long overhead lines carried on steel towers with overhead earth wires the effect of arc resistance can usually be neglected. The effect is most significant on short overhead lines and with fault currents below 2000A (i.e. minimum plant condition), or if the protected line is of wood-pole construction without earth wires. In the latter case, the earth fault resistance reduces the effective earth-fault reach of a mho Zone 1 element to such an extent that the majority of faults are detected in Zone 2 time. This problem can usually be overcome by using a relay with a cross-polarised mho or a polygonal characteristic.

Taking required primary resistive reach coverage of 4.8049 Ω for phase faults and assuiming the typical earth fault coverage of 13.25 Ω, minimun secondary reaches become :

$$
\begin{aligned}
R_{Ph_{min}} &= 4.8049 * 0.55 \\
&= 2.6426\Omega(Secondary) \qquad (3.13) \\
R_{G_{min}} &= 13.25 * 0.55 \\
&= 7.2875\Omega(Secondary) \qquad (3.14)
\end{aligned}
$$

Resistive reaches should be chosen between the calculated values as shown in the table below:

Table V: Resistive Reach Setting

	Minimum	**Maximum**	**Zone-1**	**Zone-2**	**Zone-3**
R_{Ph} Ω	2.6426	38.1054	4	30	39
R_G Ω	7.2875	50.8072	8	38	50

3.5 Zone Time Delay Setting

Proper co-ordination of the distance relay settings with those of other relays is required. Independent timers are available for the three zones to ensure this.

For Zone 1, instantaneous tripping is normal. A time delay is used only in cases where large d.c. offsets occur and old circuit breakers, incapable of breaking the instantaneous d.c. component, are involved. Considering that zone-2 and Zone-3 dealing with line joining two substations, there can be delay set for both the zones.

$T_{Z1} = 0$

$T_{Z2} = 300$ ms

$T_{Z3} = 750$ ms

$T_{Z4} = 1$ sec

The above calculations are for setting MHO characteristics and Quadrilateral characteristics as per given in MiCOM Technical manual.

3.6 REL 670

Now, the calculations will be done for REL 670 relay which is ABB make. As per given in MiCOM P444 guide, all impedance were related to secondary side whereas in REL 670 relay, impedance relate to primary side.[1]

3.6.1 Load Resistance

Considering CT Ratio as full-load current, value of resistance at this value of current is:

$$\begin{aligned} R_L &= \frac{0.8 * (PT\ Primary) * 1000}{\sqrt{3} * (Primary\ full\ load\ current)} \\ &= \frac{0.8 * (400) * (1000)}{\sqrt{3} * (2000)} \\ &= 76.98\Omega (Primary) \qquad (3.15) \\ R_F PP &= 0.6 * R_L \\ &= 46.2\Omega (Primary) \qquad (3.16) \\ R_F PE &= 0.8 * R_L \\ &= 61.6\Omega (Primary) \qquad (3.17) \end{aligned}$$

Equation 3.15 gives the total load resistance at full load current. This load resistance is necessary in calculating the resistive reaches for Phase-Phase faults and Phase-

Earth faults. The Resistive reach for Phase-Phase faults is calculated in equation 3.16 and for Phase-Earth fault in equation 3.17.

3.6.2 Zone-wise Caculation

As per given in REL guide, it calculates individual resistance and reactance reach for zero sequence components and positive sequence components separately.
The Calculation for different zones are as shown below:
For Zone-1 :

$$R_1 = 4.027 * 0.8$$
$$= 3.2216\Omega/phase \tag{3.18}$$
$$X_1 = 42.701 * 0.8$$
$$= 34.1608\Omega/phase \tag{3.19}$$
$$R_0 = 35.719 * 0.8$$
$$= 28.57\Omega/phase \tag{3.20}$$
$$X_0 = 142.100 * 0.8$$
$$= 113.68\Omega/phase \tag{3.21}$$

For Zone-2 :

$$R_1 = 100\%\ of\ Protected\,line\,resistance + 25\%\ of\ Transformer\ Impedance$$
$$= 4.027 + (0.25 * 31.75)$$
$$= 11.9645\Omega/phase \tag{3.22}$$
$$X_1 = 100\%\ of\ Protected\,line\,reactance + 25\%\ of\ Transformer\ Impedance$$
$$= 42.701 + (0.25 * 31.75)$$
$$= 50.6385\Omega/phase \tag{3.23}$$
$$R_0 = 35.719 + (0.25 * 31.75)$$

$$= 43.6565\Omega/phase \tag{3.24}$$

$$X_0 = 142.100 + (0.25 * 31.75)$$

$$= 150.0375\Omega/phase \tag{3.25}$$

For Zone-3 :

$$R_1 = 100\% \, of \, Protected \, line \, resistance + 50\% \, of \, Transformer \, Impedance$$

$$= 4.027 + (0.5 * 31.75)$$

$$= 19.902\Omega/phase \tag{3.26}$$

$$X_1 = 100\% \, of \, Protected \, line \, reactance + 50\% \, of \, Transformer \, Impedance$$

$$= 42.701 + (0.5 * 31.75)$$

$$= 58.576\Omega/phase \tag{3.27}$$

$$R_0 = 35.719 + (0.5 * 31.75)$$

$$= 51.594\Omega/phase \tag{3.28}$$

$$X_0 = 142.100 + (0.5 * 31.75)$$

$$= 157.975\Omega/phase \tag{3.29}$$

For Zone-4 :

$$R_1 = 0.1 * R_1 \, of \, Zone - 1$$

$$= 0.32216\Omega/phase \tag{3.30}$$

$$X_1 = 0.1 * X_1 \, of \, Zone - 1$$

$$= 3.41608\Omega/phase \tag{3.31}$$

$$R_0 = 0.1 * R_0 \, of \, Zone - 1$$

$$= 2.857\Omega/phase \tag{3.32}$$

$$X_0 = 0.1 * X_0 \, of \, Zone - 1$$

$$= 11.368\Omega/phase \tag{3.33}$$

Chapter 4

Simulation and Results

4.1 System Resprentation

The line for which the Distance Protection scheme is developed is between Rajpura to Nakodar. The line is of 139km distance and of 400kV.

The modelling is developed using PSCAD/EMTDC software. It is as shown in figure 4.1.

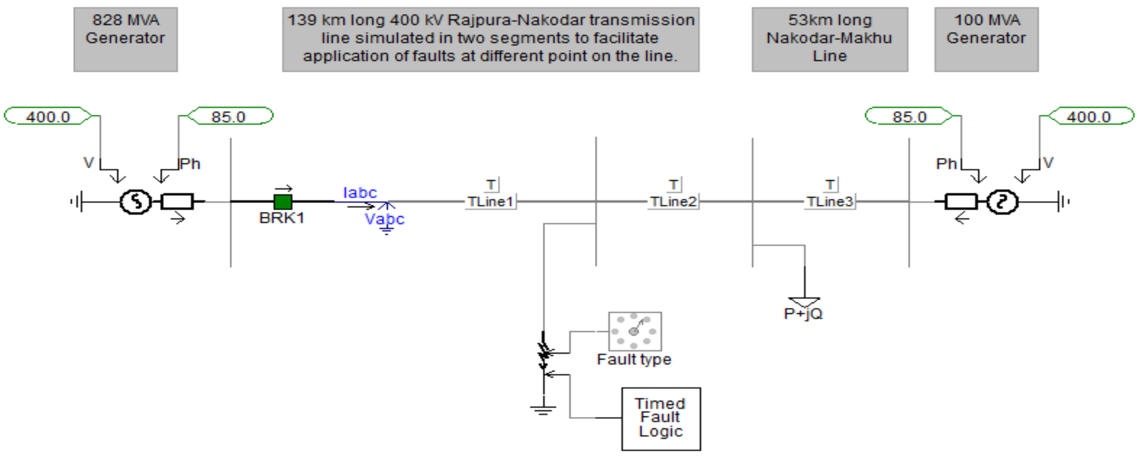

Figure 4.1: Single Line Diagram

The main protected line which is the line between Rajpura TPPS-Nakodar is sectionalized in two parts to facilitate faults at different locations. The shortest adjacent line to main protected line is the line from Nakodar-Makhu. I_{abc} and V_{abc} measures the current and voltage respectively.

4.2 CT and CCVT Block

The voltage and Current which the Voltmeter and Ammeter reads will be given as input to the CT and CCVT block. The rating for CT is 2000/1 A. The rating for CCVT includes PT Ratio equals to 400 kV/ 110 V. Its Primary and Secondary capacitance is 4468.0 pF and 130129.0 pF respectively and Inductance is 42 H. The blocks are as shown in figure 4.2 and 4.3 respectively.

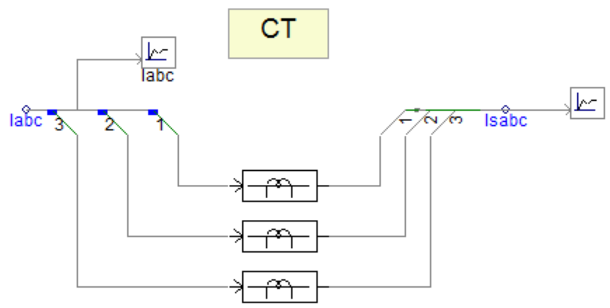

Figure 4.2: CT Block

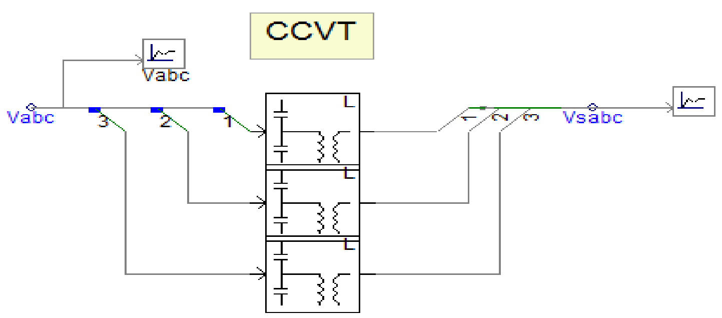

Figure 4.3: CCVT Block

4.3 Distance Relay Module

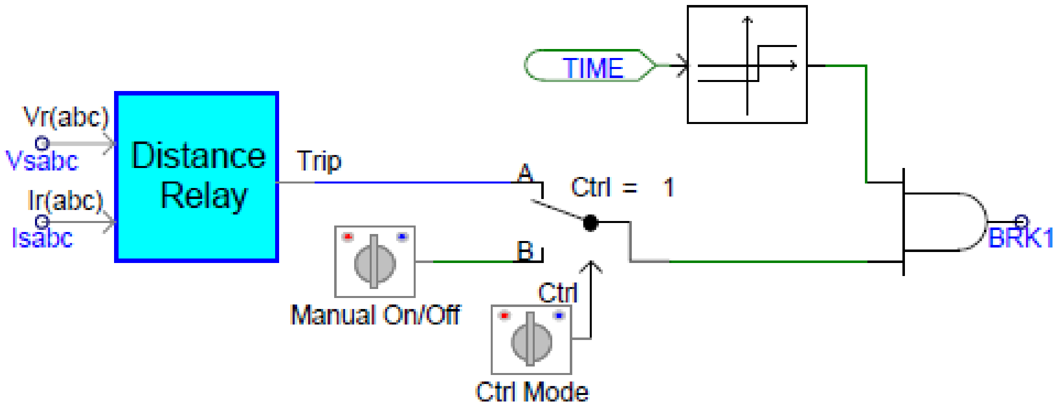

Figure 4.4: Distance Relay Module

The output from CT and CCVT blocks will be given to the distance relay module. By opening module, the output of CT and CCVT is given to FFT blocks. The control of both the breakers are done by distance relay block. Breaker-1 can be operated manually as well as on auto mode. If it is kept on auto mode, it follows distance protection scheme and if it is kept on manual mode, it can be made open/close manually. The distance relay module is shown in figure 4.4.

4.4 FFT Block

For the calculation point of view, we deal with fundamental components only. So, the output from CT and CCVT blocks are given to FFT blocks which will convert the components to fundamental components. The FFT Block is as shown in figure 4.5.

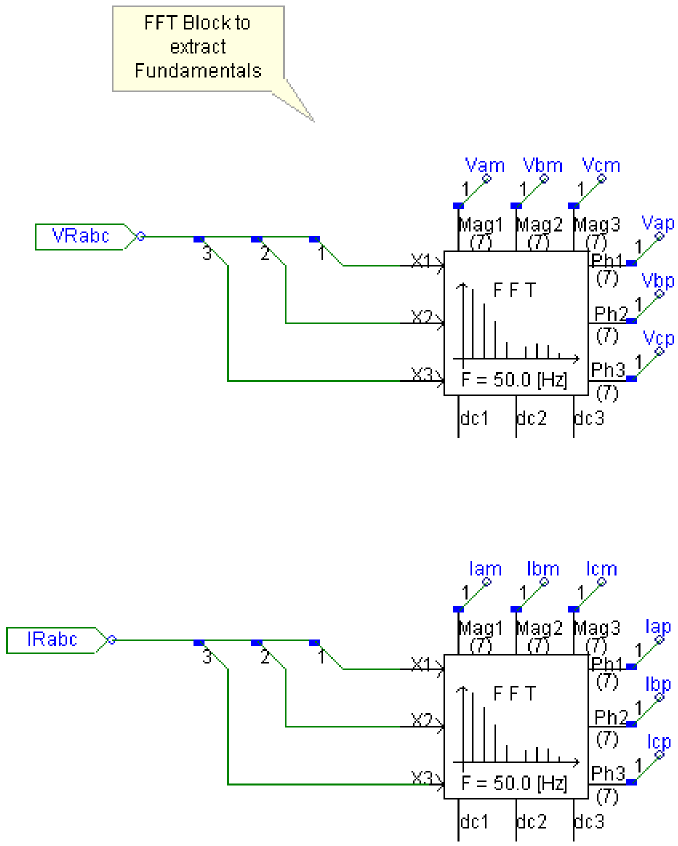

Figure 4.5: FFT Block

In PSCAD/EMTDC, there are three type of FFT blocks.

1-phase: This is a standard 1-phase FFT. The input is processed to provide the magnitudes Mag and phase angle Ph of the fundamental frequency and its harmonics (including the DC component dc).

2-phase: This is nothing more than two 1-phase FFTs in a single block, in order to keep things compact and organized.

3-phase: As above, is merely three 1-phase FFTs combined in one block.

+/-/0 seq: This takes a 3-phase input XA, XB, XC and calculates the FFT preliminary output through a sequencer, which outputs positive (+), negative (-), and zero-sequence magnitude and phase components of the fundamental, and each harmonic. The DC components of each phase are also output.

The output of FFT block for Voltage and Current Waveform will be given to respective Sequence Filter.

4.5 Sequence Filter

For the calculation of Line-Ground Impedance, Zero Sequence Current is required. So, this is obtained from Sequence Filter. Fundamental components are given as input to Sequence Filter which gives output as sequential components. This Sequence Filter calculates the magnitudes and phase angles of sequence components, when the magnitudes and phase angles of the phase quantities are given.Figure 4.6 shows the sequence filter.

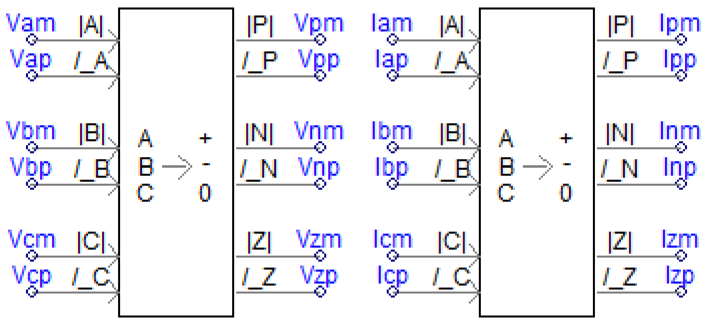

Figure 4.6: Sequence Filter Block

4.6 Line-Line and Line-Ground Impedance

The components shown below in figure 4.7 computes the line-to-line and line-to-ground impedance as seen by a ground impedance relay. The output impedance is in rectangular format (R and X), and is optimized for use with the Trip Polygon, Distance Relay - Apple Characteristics, Distance Relay - Lens Characteristics or the Mho Circle trip devices. For Line-Ground Impedance measurements, zero sequence current is required so for that Residual Compensation Factor is required which is already calculated in above chapter.

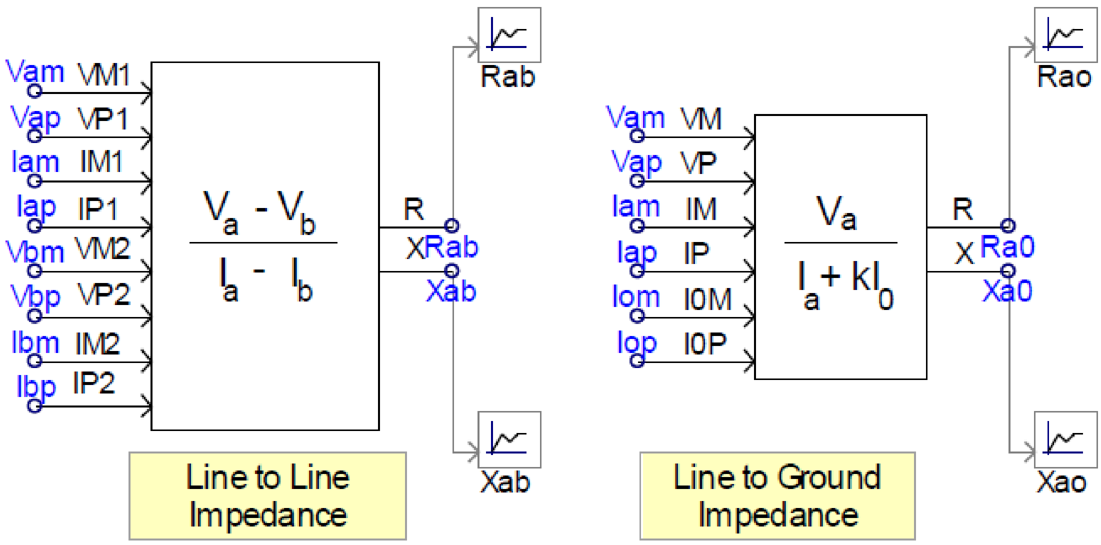

Figure 4.7: Impedance Block

4.7 Relay Block

The MHO Circle component is classified as an 'Impedance Zone Element', which checks whether or not a point described by inputs R and X, lies inside a specified region on the impedance plane. R and X represent the resistive and reactive parts of the monitored impedance, and may be input in per-unit or ohms. Please note however, that the units of the component input parameters should match that of the R and X inputs. The component produces an output '1' if the point defined by R and X is inside the specified region, otherwise the output will be '0'.

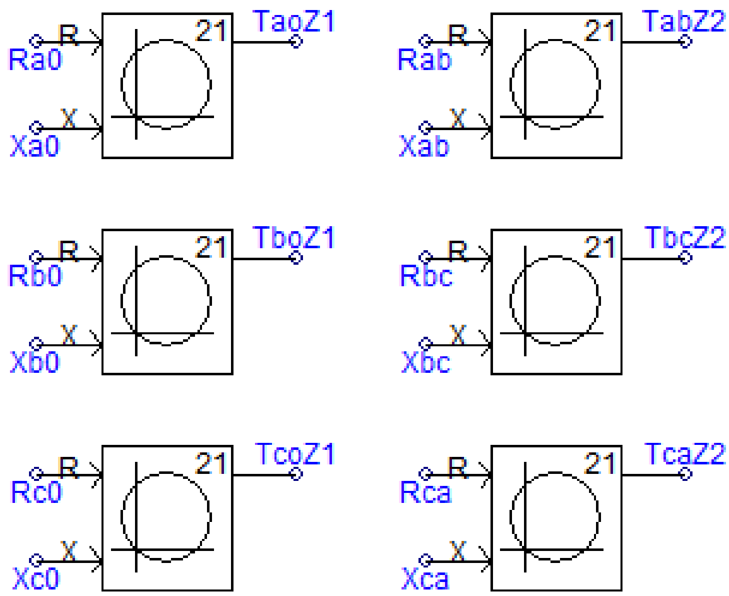

Figure 4.8: MHO Relay

The above shown block in figure 4.8 is applicable for MHO Characteristics only; while plotting Quadrilateral characteristics, it will be different.

4.8 Tripping Logic

The logic of tripping Signals is as shown below in figure 4.9.

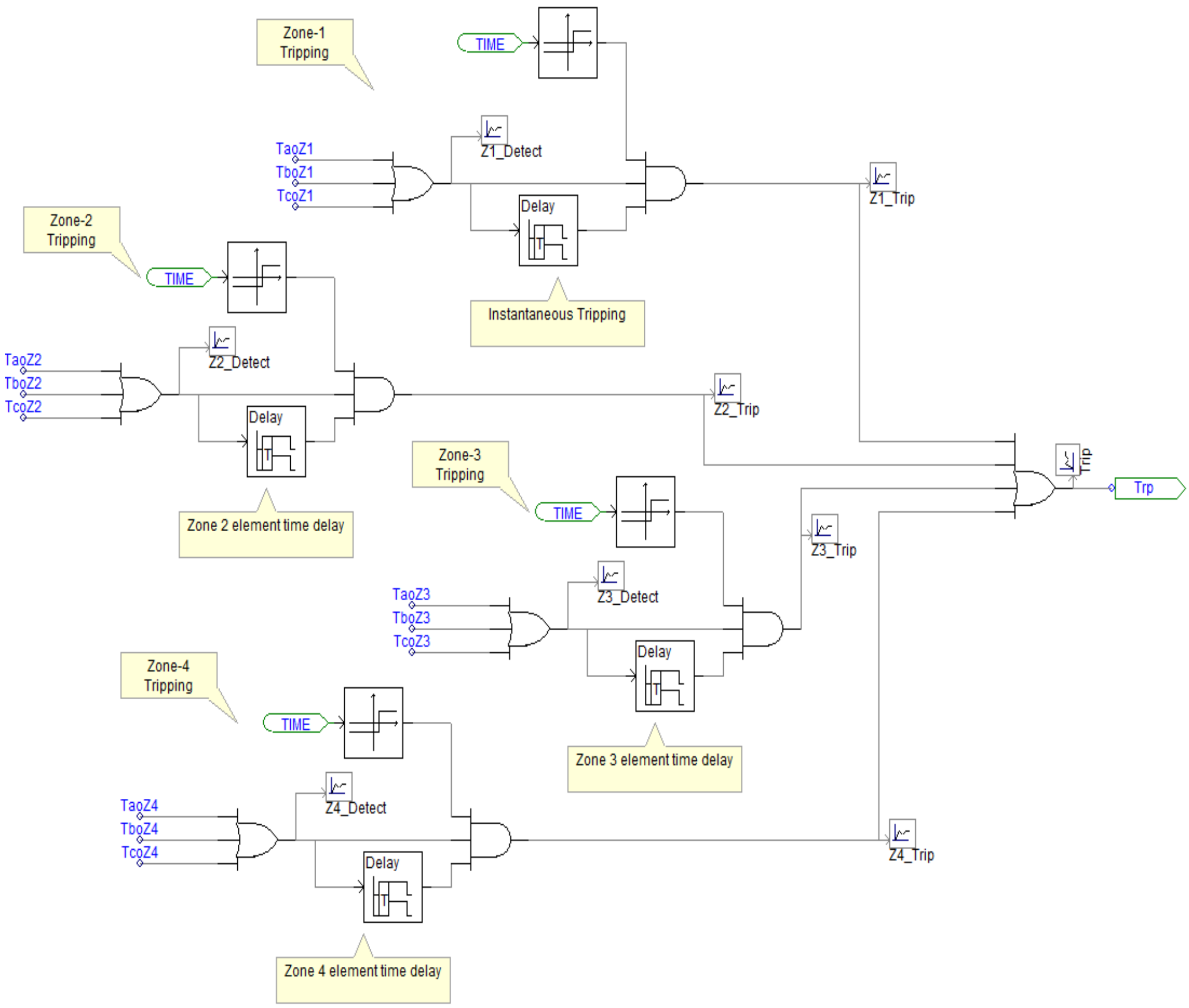

Figure 4.9: Tripping Signals

Is the fault impedance enters the characteristics defined in MHO Relay; it will give output 1. It will check that in which zone, the impedance is seen. If it enters into the zone; it will be shown by Zone-Detect Plot and if that impedance remains for the predefined time, that particular zone will get the tripping signal. Zone-1 operates instantaneously but all the other zones are defined particular time delay.

4.9 Algorithm for MHO Characteristics

This is how the MHO Characteristics Algorithm works. It will follow the sequence as shown in the below given Algorithm (figure 4.10).

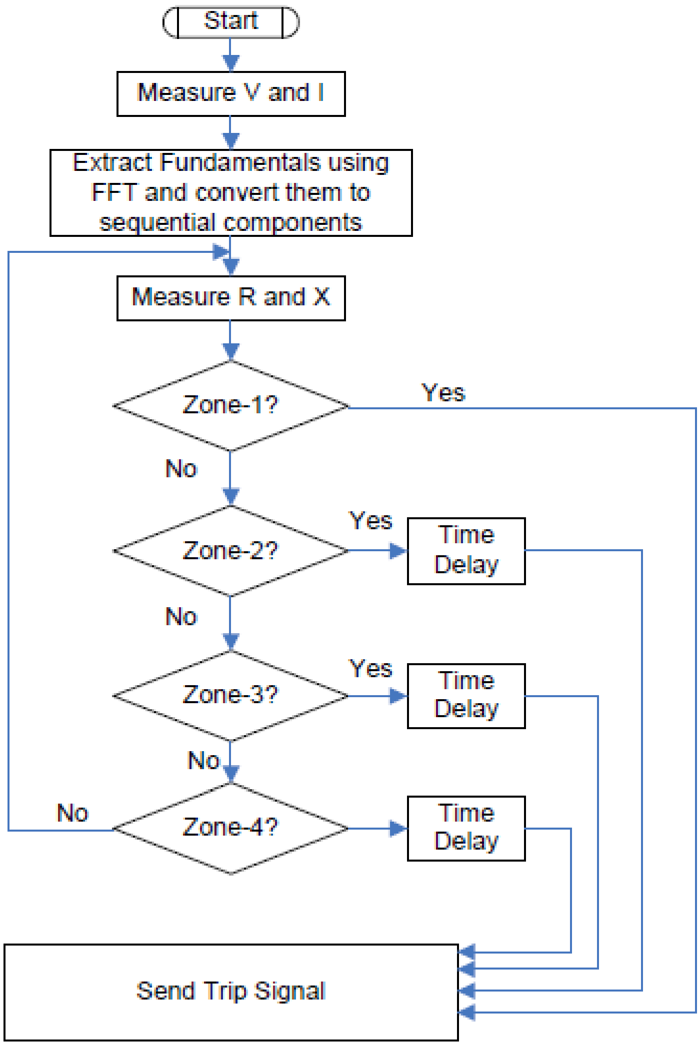

Figure 4.10: MHO Algorithm

4.10 Plotting MHO Circle

Now, to plot actual MHO characteristics on X-Y plot, we require equations. Those are as shown below in figure 4.11 according to the calculated value.

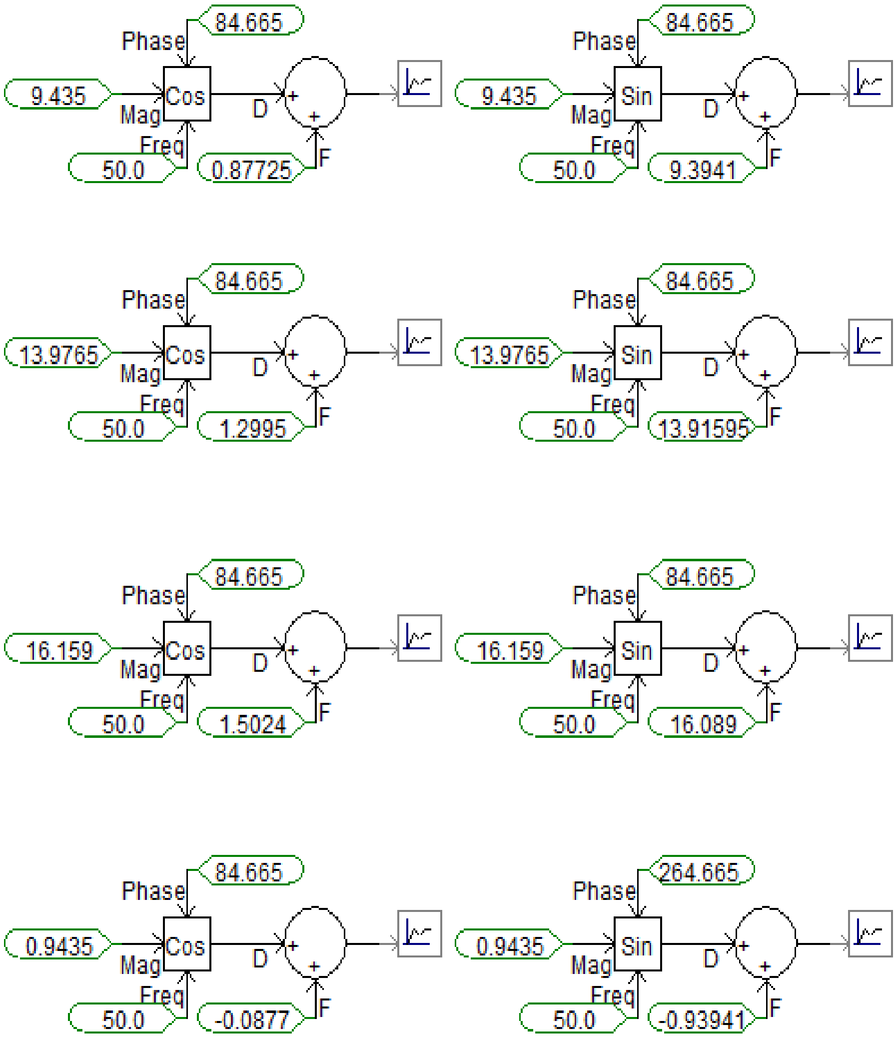

Figure 4.11: Plotting MHO Circle

Now, the fault will be created and the performance of MHO characteristics will be analysed. The MHO Characteristics and the Trip signal will be shown in the plots.

4.11 MHO Circle

4.11.1 Case-1

When the single line to ground fault is created at 25 kms from A; the MHO circle looks like as it is shown below in figure 4.12. First the impedance enters zone-3, then zone-2 and zone-1 respectively. Once, it enters the reach of zone-1, it gets tripped as the Zone-1 is assigned instantaneous tripping.

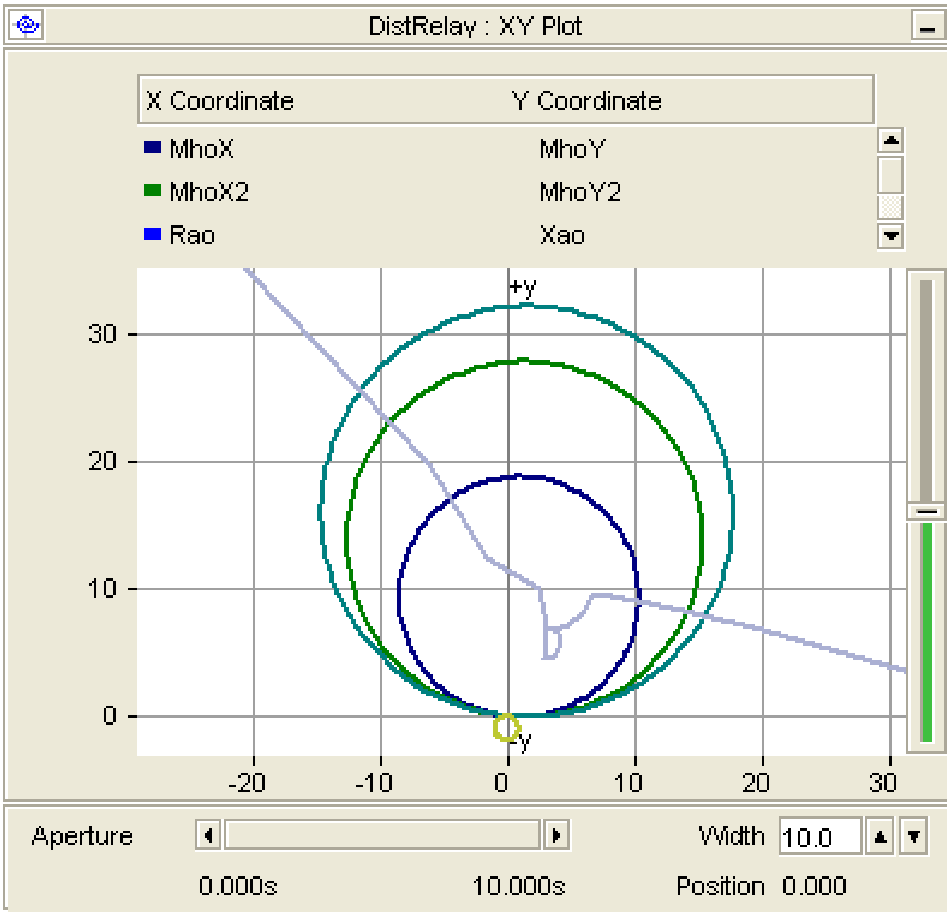

Figure 4.12: MHO Relay Circle after fault at 25 kms

Figure 4.13 shows the tripping signal when L-G fault is created at 25 kms away from A. Above plot shows which zone gets the trip signal and below plot shown for how much duration, the impedance lie in all zones.

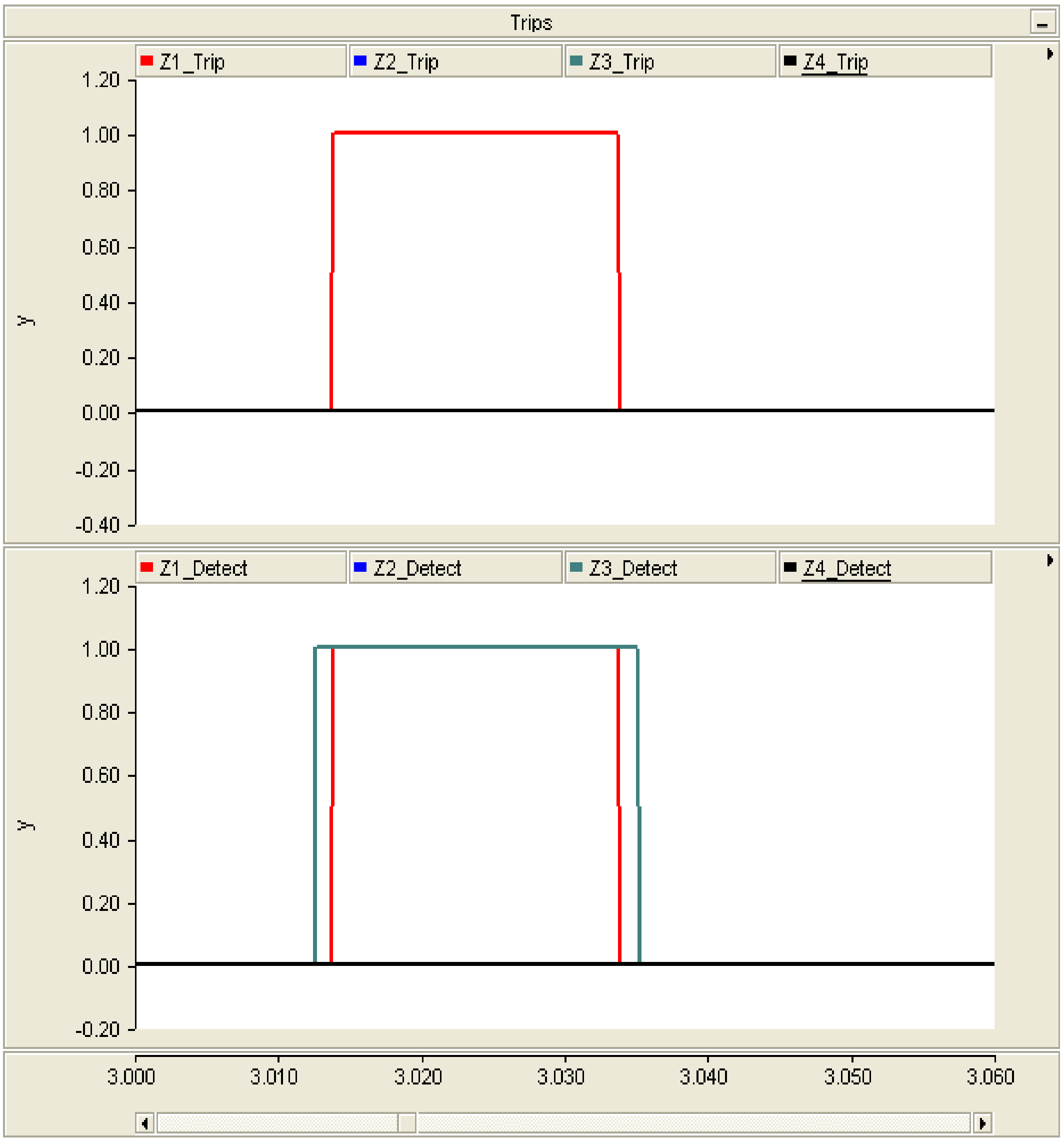

Figure 4.13: Trip during fault at 25 kms

4.11.2 Case-2

When the single line to ground fault is created at 120 kms from A; the MHO circle looks like as it is shown below.As it is seen in figure 4.14, first the impedance enters zone-3 , Zone-2 and then zone-1. Once, it enters the reach of zone-1, it gets tripped.

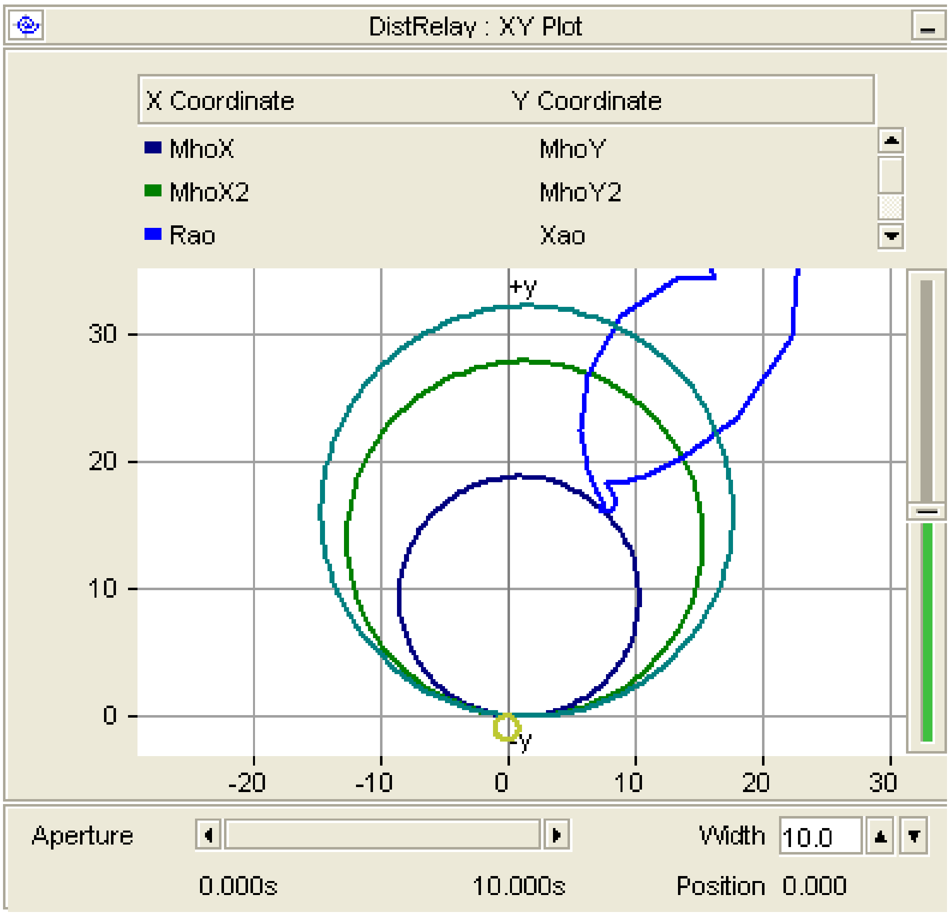

Figure 4.14: MHO Relay Circle after fault at 120 kms

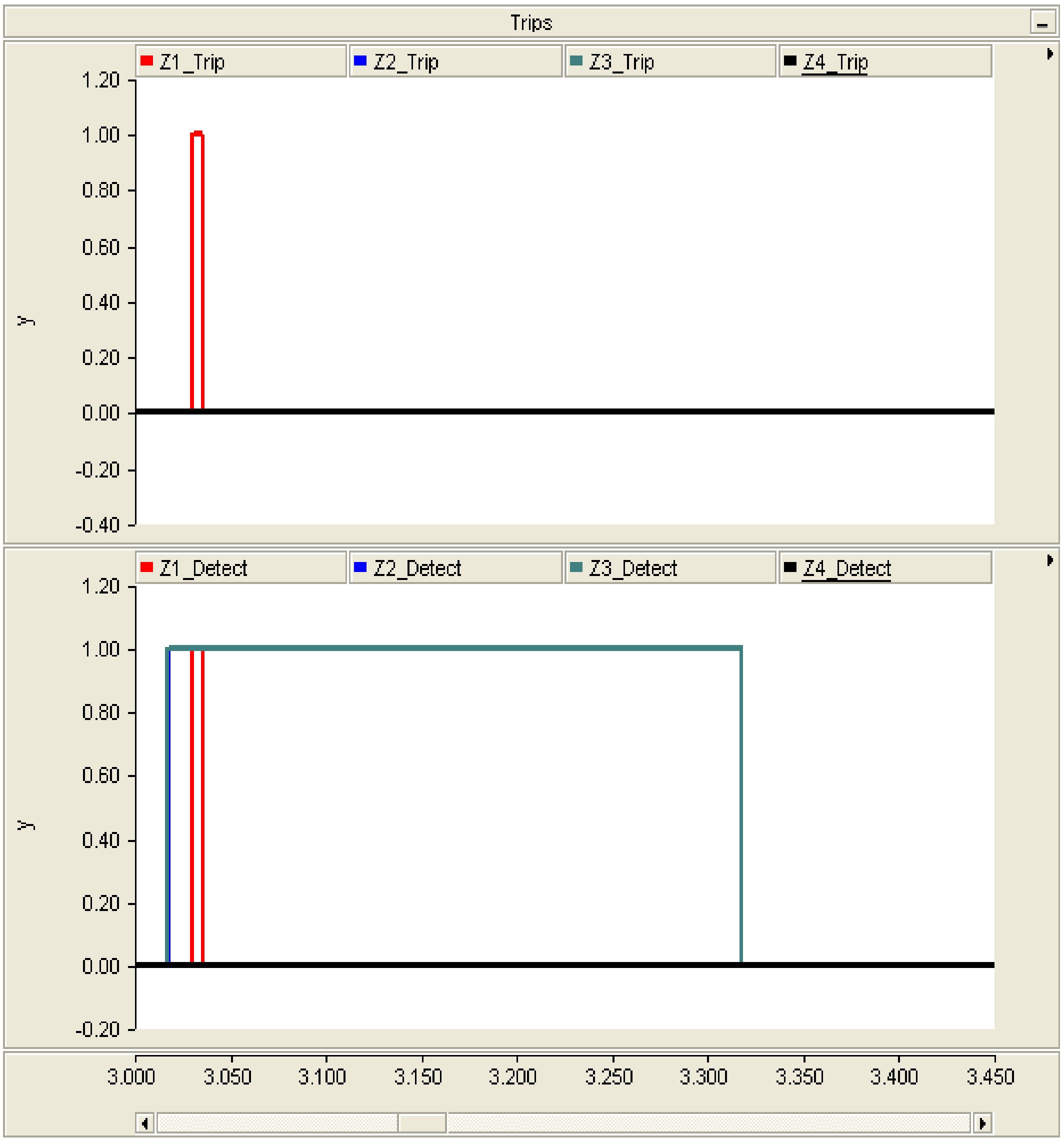

Figure 4.15: Trip during fault at 120 kms

Figure 4.15 shows the tripping signal when L-G fault is created at 120 kms away from A. Above plot shows which zone gets the trip signal and below plot shown for how much duration, the impedance lie in all zones.

4.12 Mho circle with fault resistance

Line-Line fault with different fault resistance were applied on the transmission line at a location 120 kms from bus-A, zone 1 with different fault resistances. Below figures shows the behavior of the mho relay when fault resistance is 5 Ω,20 Ω and 22 Ω. When the fault resistance is 5 Ω the relay detects the fault in zone 1. Due to increase in fault resistance to 20 Ω and 22 Ω, impedance seen by the relay lies in the zone2 and Zone3 as shown below. Thus, mho relay under reaches due to fault resistance.[9]

4.12.1 Case-1

When the line-line fault is created at 120 kms with R_f =5 Ω ; the MHO circle looks like as it is shown below.As it is seen in figure 4.16, first the impedance enters zone-3, Zone-2 and then zone-1. Once, it enters the reach of zone-1, it gets tripped.

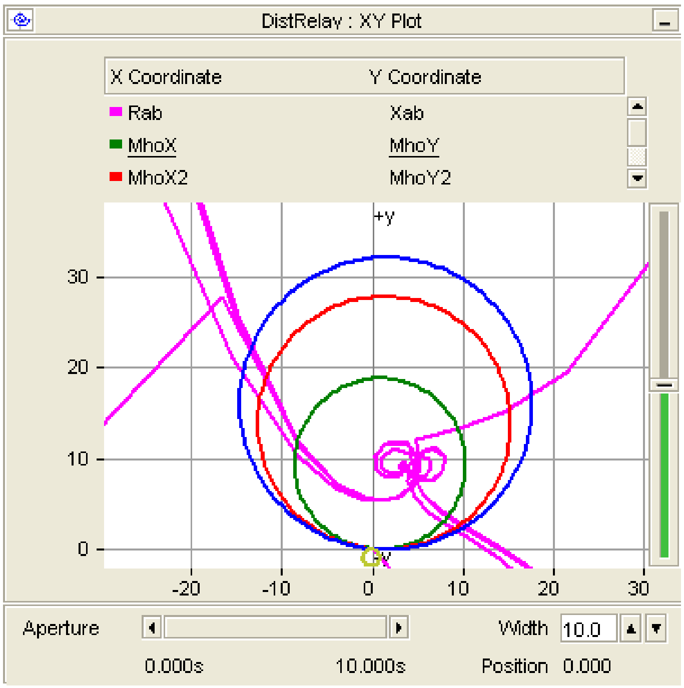

Figure 4.16: MHO Relay Circle after fault at 120 kms with R_f = 5 Ω

4.12.2 Case-2

When the line-line fault is created at 120 kms from A; the MHO circle looks like as shown in below figure.As it is seen in figure 4.17, first the impedance enters zone-3 and then Zone-2. Once, it enters the reach of zone-2, the faulty impedance is seen for the delay time set for Zone-2.

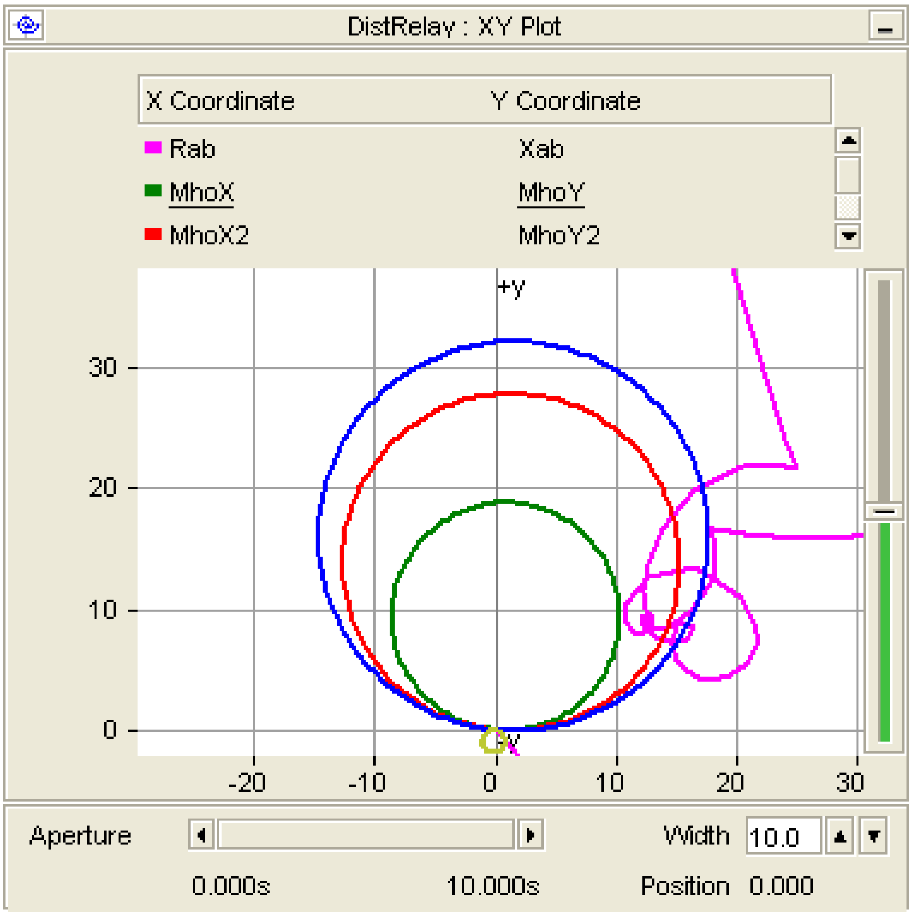

Figure 4.17: MHO Relay Circle after fault at 120 kms with $R_f = 20\ \Omega$

Figure 4.18 shows the tripping signal when L-L fault is created at 120 kms away with $R_f = 20\ \Omega$. Above plot shows which zone gets the trip signal and below plot shown for how much duration, the impedance lie in all zones.

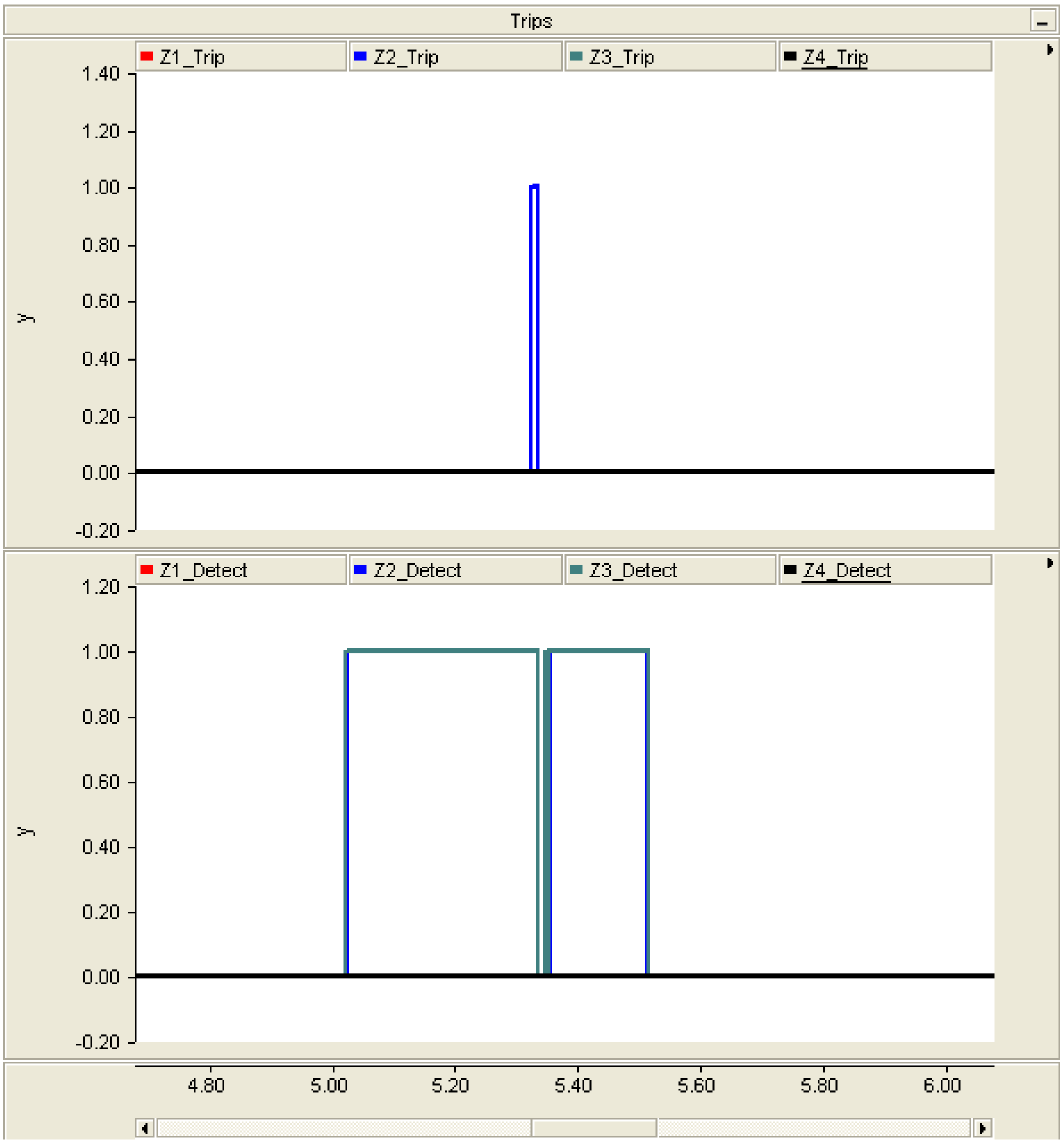

Figure 4.18: Trip during fault at 120 kms with $R_f = 20\ \Omega$

4.12.3 Case-3

When the line-line fault is created at 120 kms with R_f =22 Ω, the MHO circle looks like as it is shown below.As it is seen in figure 4.19, the impedance enters zone-3 and remains in that region for more than delay time set. So, Zone-3 gets Tripping Signal.

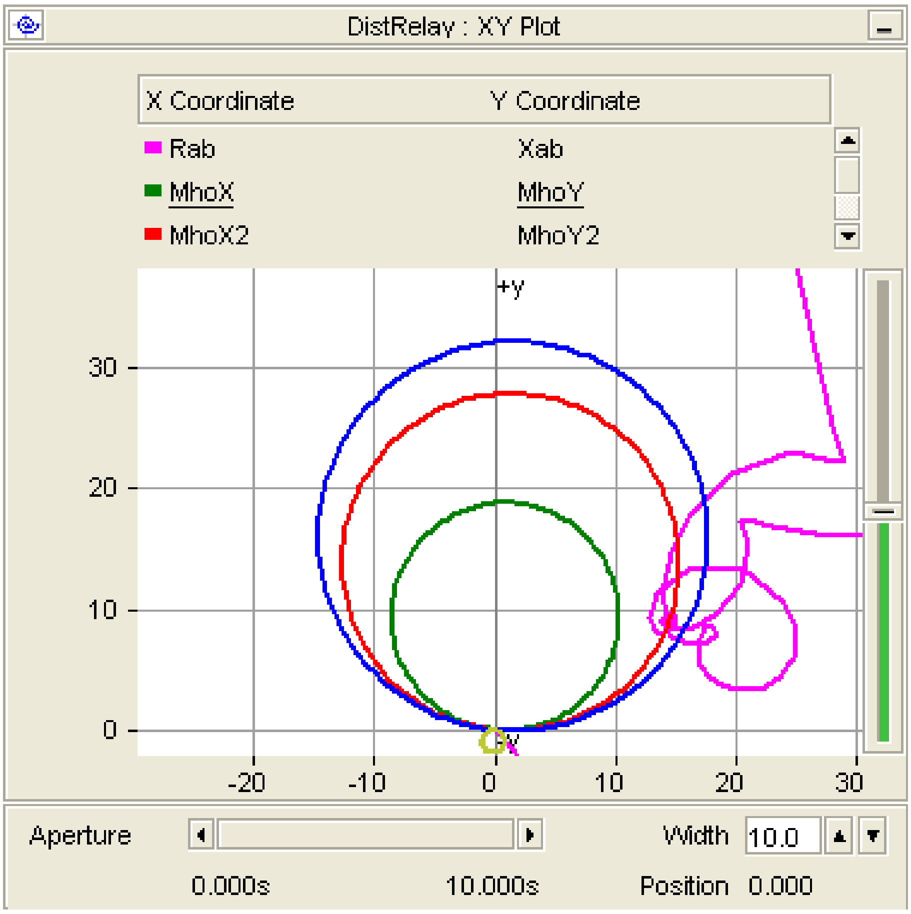

Figure 4.19: MHO Relay Circle after fault at 120 kms with R_f = 22 Ω

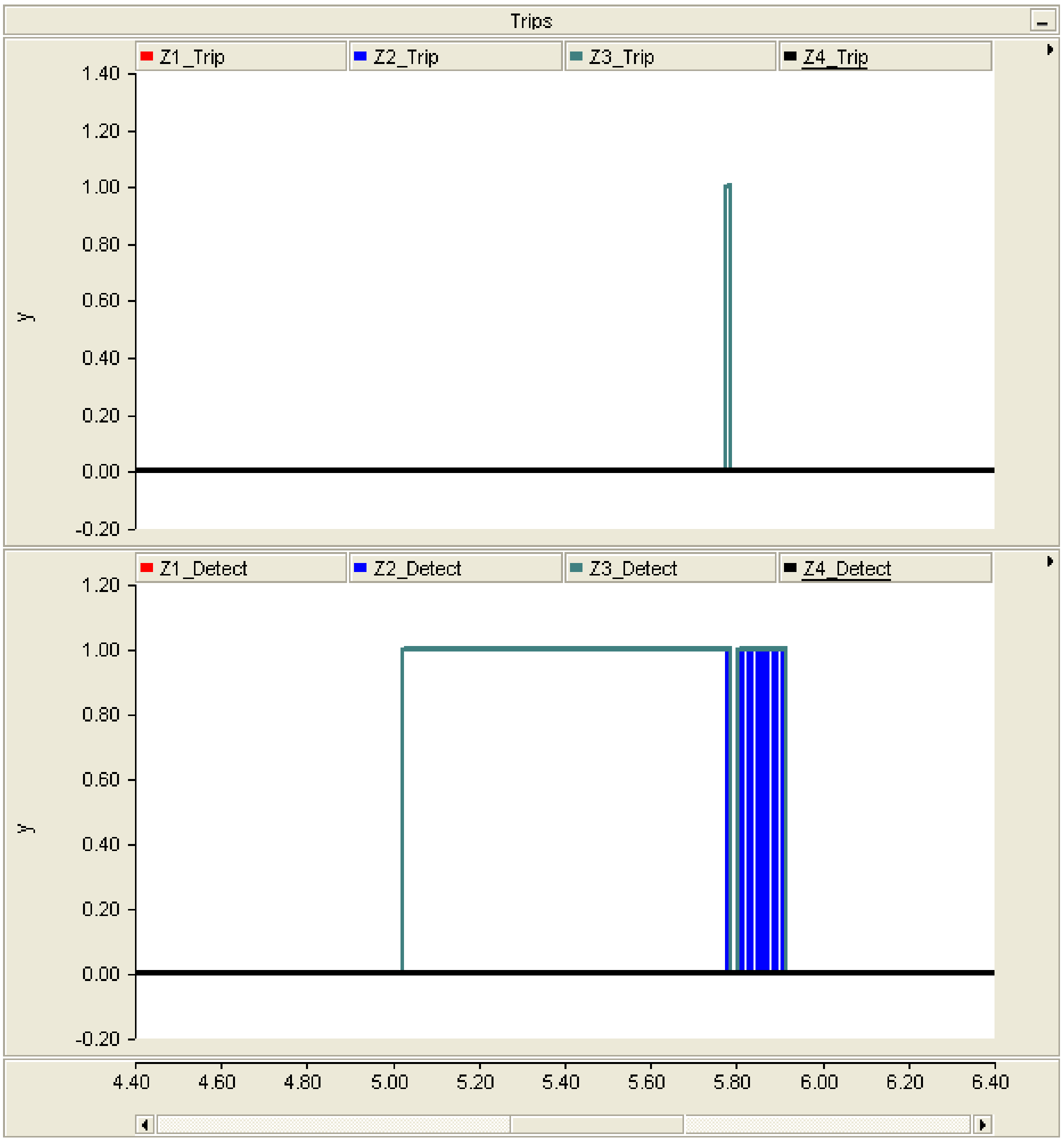

Figure 4.20: Trip during fault at 120 kms with $R_f = 22\ \Omega$

Figure 4.20 shows the tripping signal when L-L fault is created at 120 kms away with $R_f = 22\ \Omega$. Above plot shows which zone gets the trip signal and below plot shown for how much duration, the impedance lie in all zones.

4.13 Algorithm for Quadrilateral Characteristics

This is how the Quadrilateral Characteristics Algorithm works. It will follow the sequence as shown in the below given Algorithm (Figure 4.21).

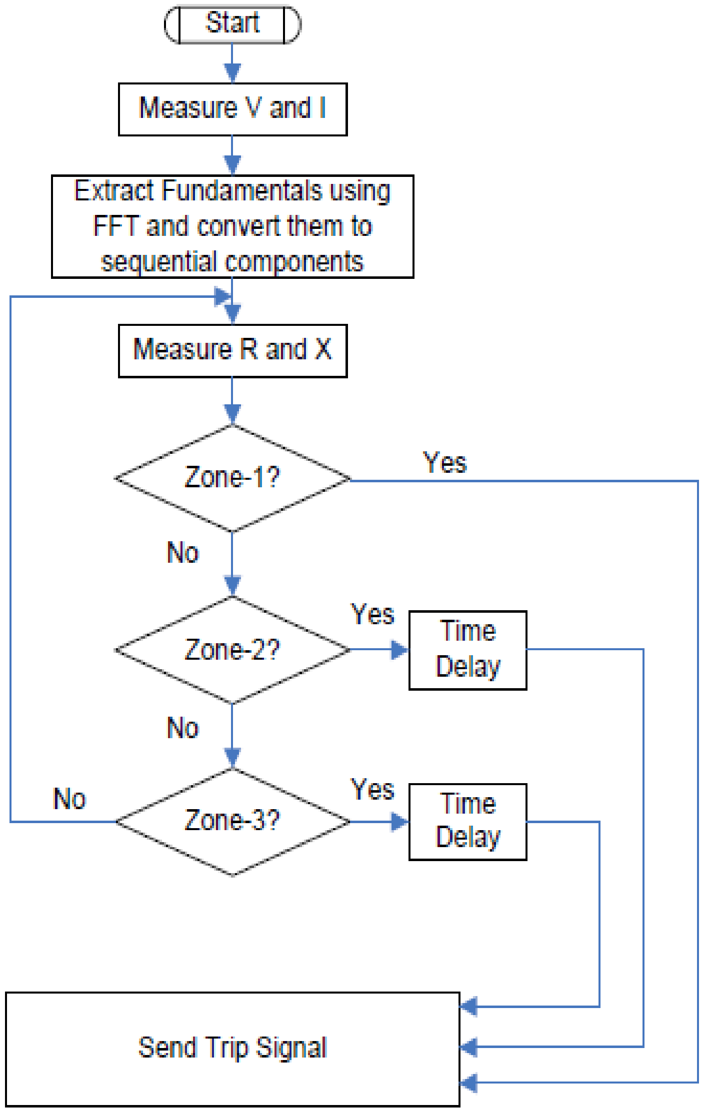

Figure 4.21: Quadrilateral Algorithm

4.14 Plotting Quadrilateral Characteristics

For plotting quadrilateral characteristics, four line equations are required. They are as shown below in figure 4.22.

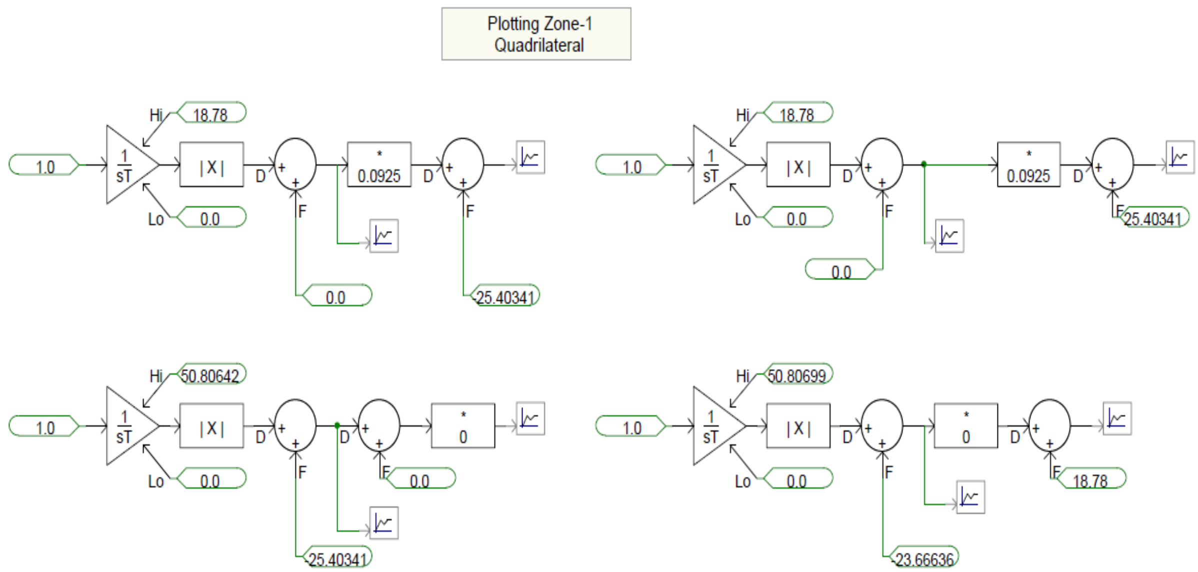

Figure 4.22: Quadrilateral Characteristics equation for Zone-1

Similar equations can be applied to all the zones for plotting quadrilaterals for respective zones with different setting parameters.

We can change the reach of the zone by changing the values in the integer box in the above figure 4.22. Also, for slant height we can adjust the slope.

4.15 Quadrilateral Characteristics for ABC-G Fault

Now, the Distance Protection case will be studied for Quadrilateral characteristics. The calculation for the Quadrilateral characteristics are shown in chapter no-3. ABC-G fault is applied to the transmission line at different locations. The behaviour of relay is studied and is simulated below.[7]

4.15.1 ABC-G Fault at 25 kms

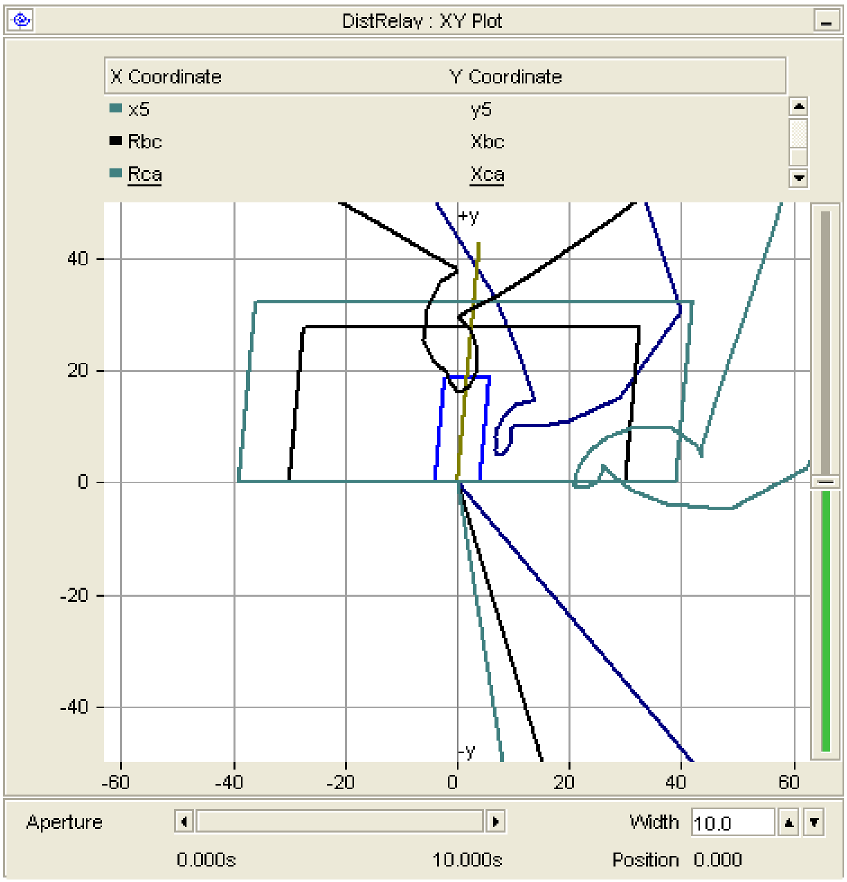

Figure 4.23: Quadrilateral Characteristics after fault at 25 kms

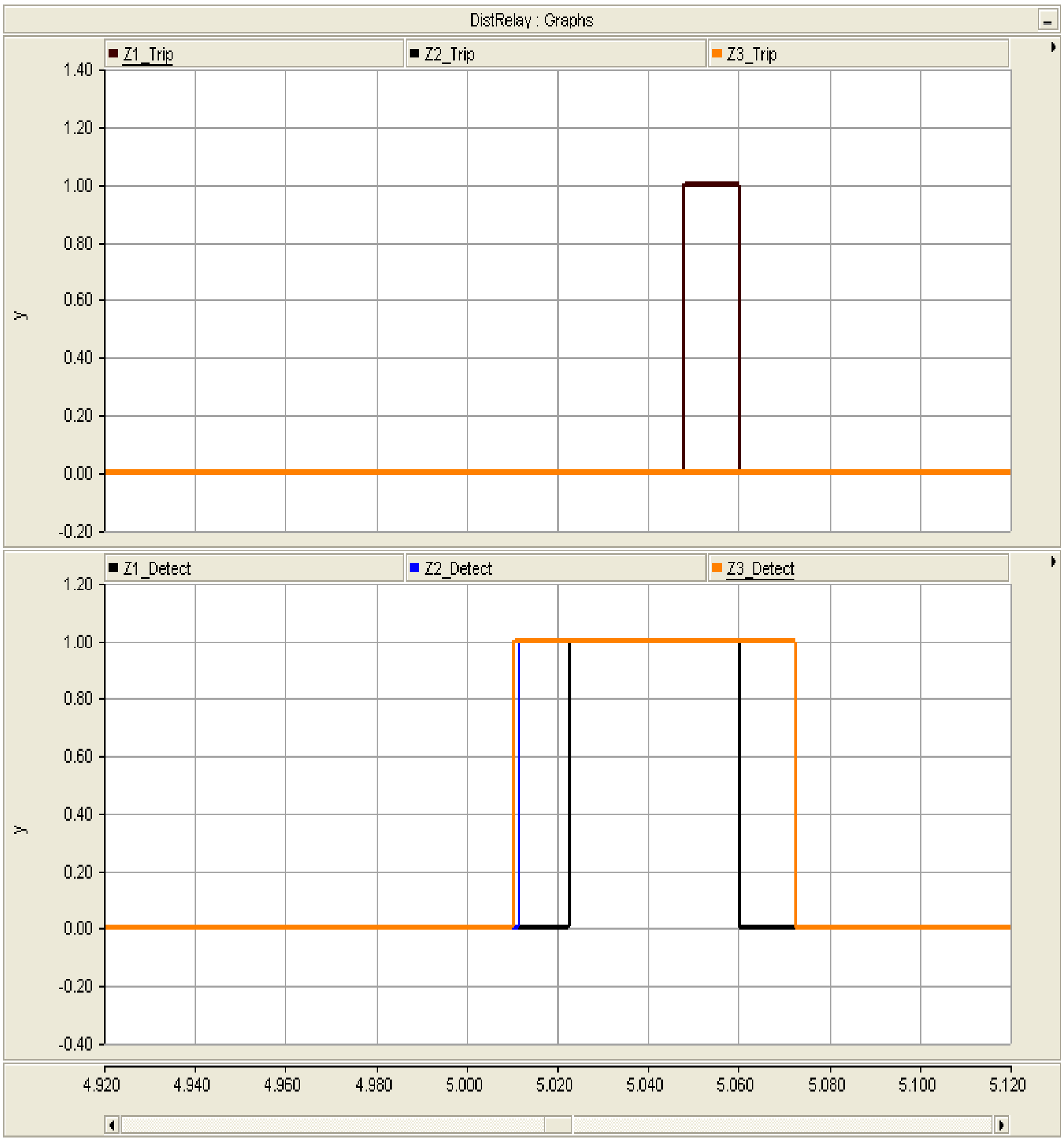

Figure 4.24: Trip during fault at 25 kms

Here, the fault is applied at 25 kms. It comes in range of 80% which is the set value of Zone-1. As shown in figure 4.23, we can see the impedance enters the zone-1 reach. As the Zone-1 reach is assigned instantaneous tripping, the Zone-1 is tripped instantaneously as is seen in figure 4.24.

4.15.2 ABC-G Fault at 130kms

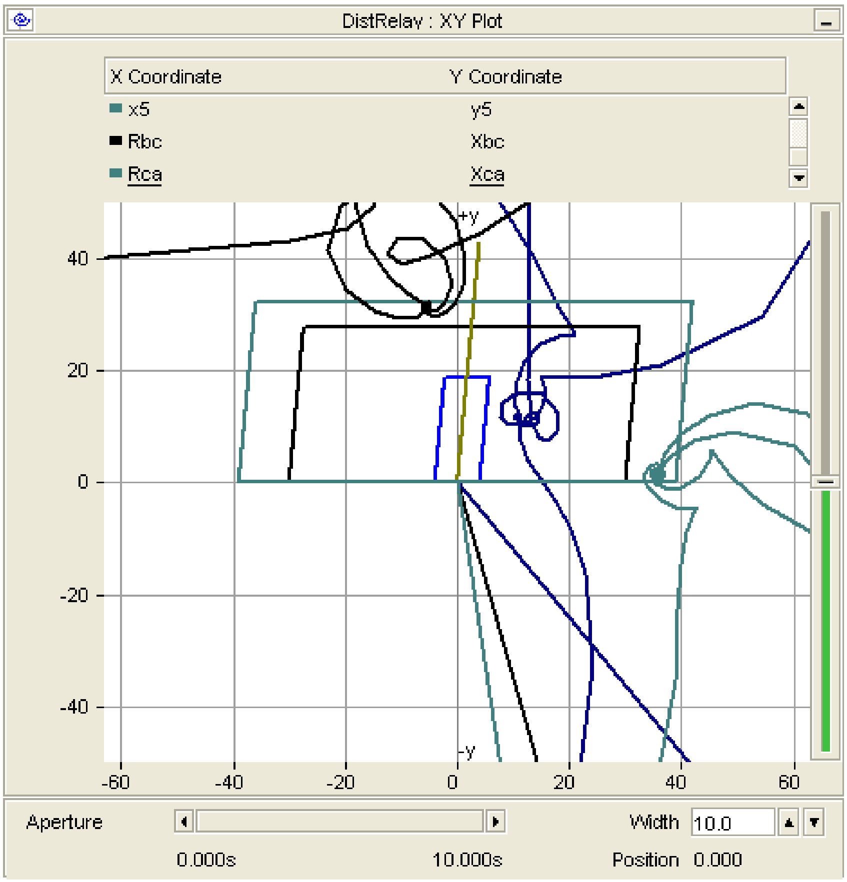

Figure 4.25: Quadrilateral Characteristics after fault at 130 kms

Here, the fault is applied at 130 kms.The set value of Zone-1 is 80% which includes 119 kms of total protected line. After this point, Zone-2 reach starts.

As shown in figure 4.25, we can see the impedance enters the zone-2 reach and remains for more than the delay time set for Zone-2.

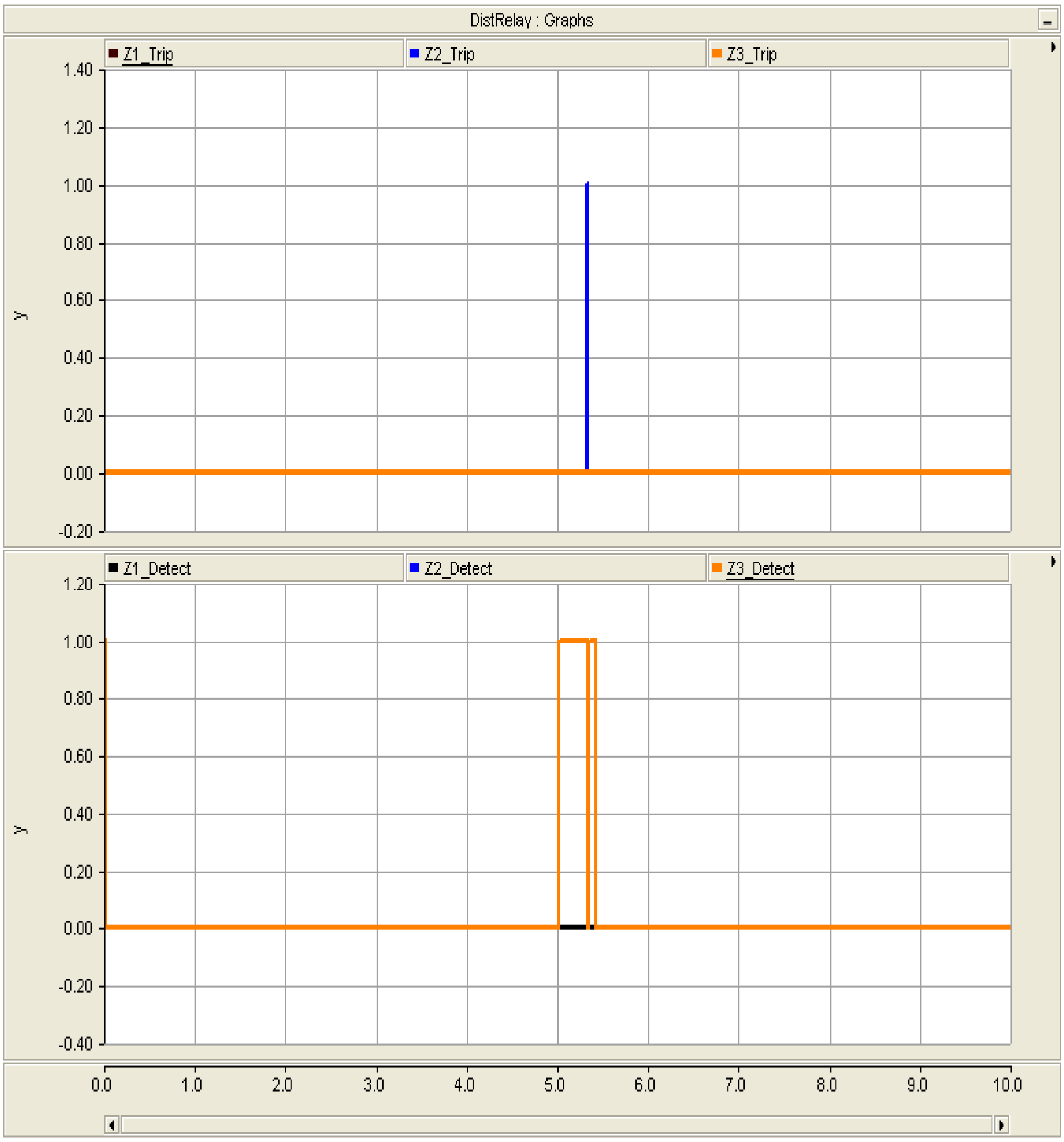

Figure 4.26: Trip during fault at 130 kms

The above shown figure 4.26 is the tripping diagram. In that figure, above plot is the tripping zone plot and below is for zone-wise detection. As the Zone-2 reach is assigned time delay of 0.3 seconds, the Zone-2 is tripped after 0.3 seconds which can be seen in figure 4.26.

4.16 Quadrilateral characteristics with fault resistance

Line-Ground fault with different fault resistance were applied on the transmission line at a location 110 kms from bus-A, zone 1 with different fault resistances. Below figures shows the behavior of the mho relay when fault resistance is 5 Ω,18 Ω and 78 Ω. When the fault resistance is 5 Ω the relay detects the fault in zone 1. Due to increase in fault resistance to 18 Ω and 78 Ω, impedance seen by the relay lies in the zone2 and Zone3 as shown below. Thus, Quadrilateral relay under reaches due to fault resistance.

4.16.1 Case-1

When the Line-Ground fault is created at 110 kms with R_f =5 Ω ; the Quadrilateral Characteristics looks like as it is shown below.As it is seen in figure 4.27, first the impedance enters zone-3, Zone-2 and then zone-1. Once, it enters the reach of zone-1, it gets tripped.

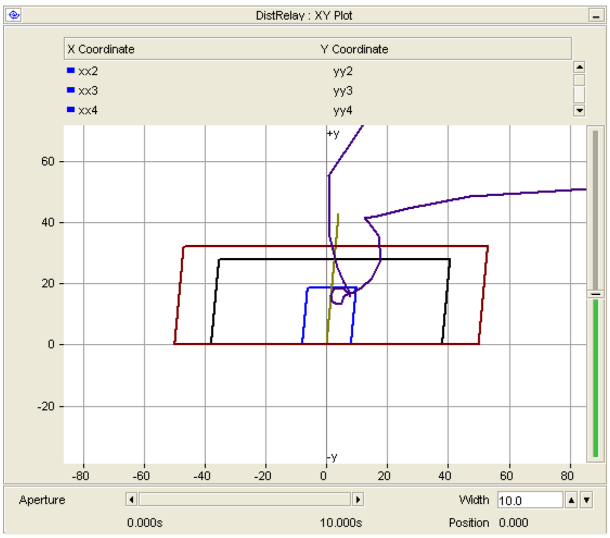

Figure 4.27: Quadrilateral Characteristics after fault at 110 kms with R_f = 5 Ω

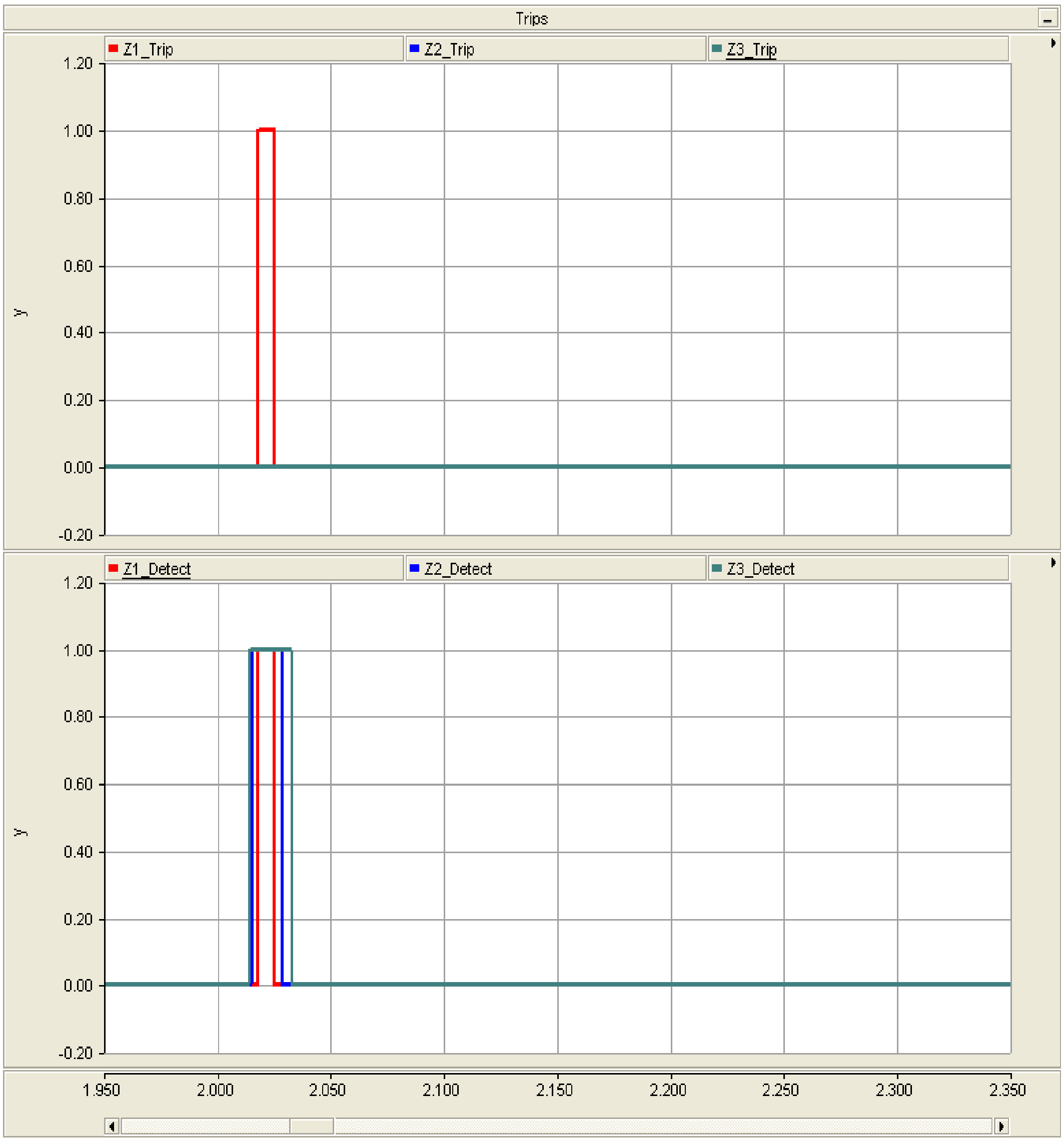

Figure 4.28: Trip during fault at 110 kms with $R_f = 5\ \Omega$

As shown in above figure 4.28, in below plot, we can see the duration for which the impedance enters different zones and in above lot, we can see the tripping signal.

4.16.2 Case-2

When the Line-Ground fault is created at 110 kms from A; the Quadrilateral Characteristics looks like as shown in below figure.As it is seen in figure 4.29, first the impedance enters zone-3 and then Zone-2. Once, it enters the reach of zone-2, the faulty impedance is seen for the delay time set for Zone-2.

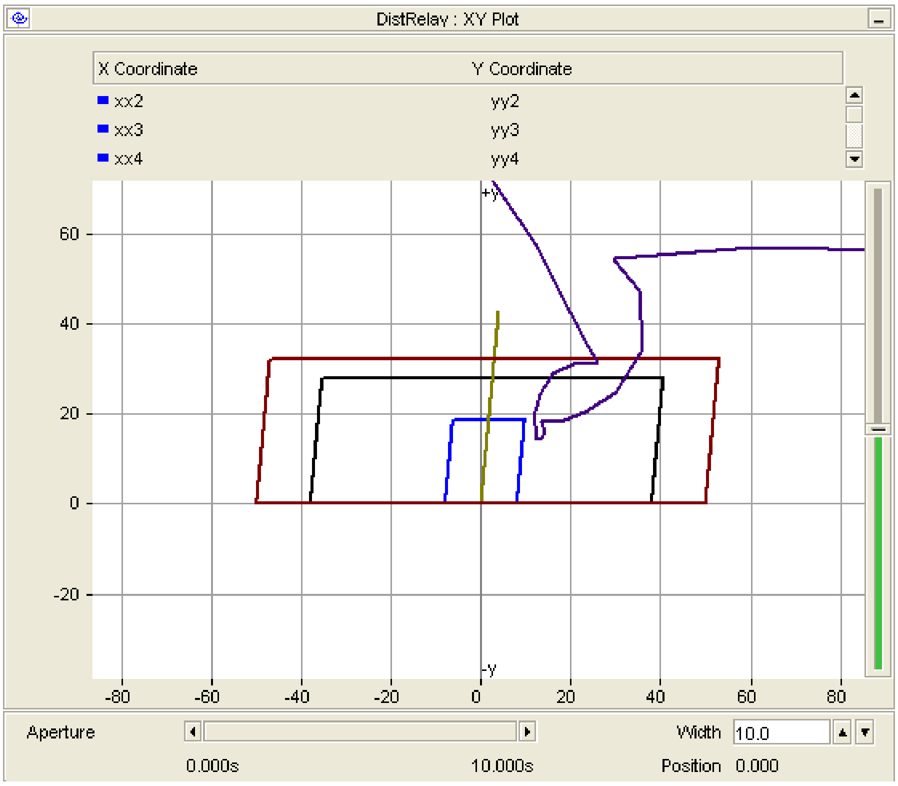

Figure 4.29: Quadrilateral Characteristics after fault at 110 kms with $R_f = 18\ \Omega$

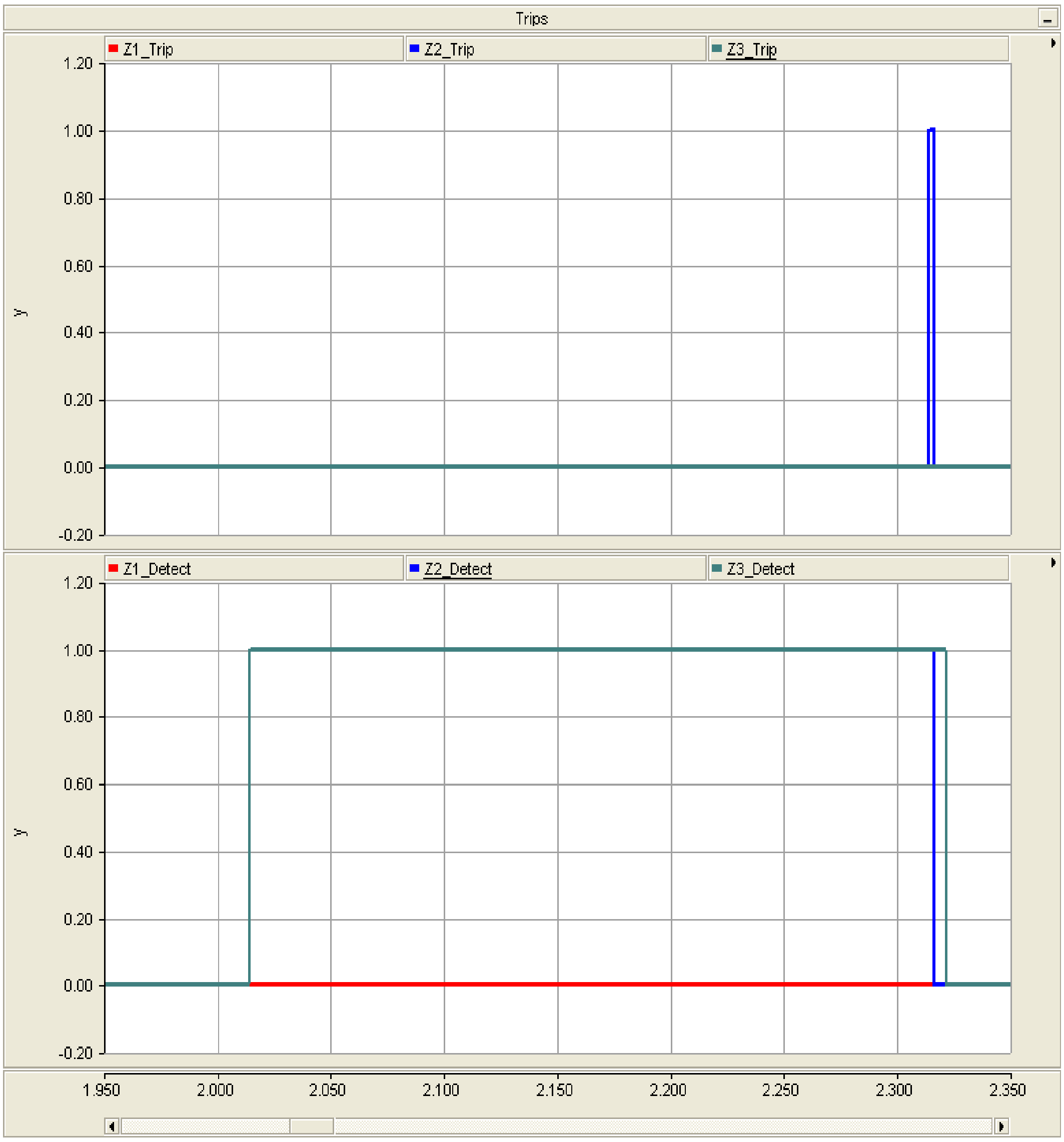

Figure 4.30: Trip during fault at 110 km with $R_f = 18\ \Omega$

Figure 4.30 shows the tripping signal when L-G fault is created at 110 kms away with $R_f = 18\ \Omega$.Above plot shows which zone gets the trip signal and below plot shown for how much duration, the impedance lie in all zones.

4.16.3 Case-3

When the Line-Ground fault is created at 110 kms with R_f =78 Ω, the Quadrilateral Characteristics looks like as it is shown below.As it is seen in figure 4.31, the impedance enters zone-3 and for the defined time, it pertains in the defined zone. So, Zone-3 gets Tripping Signal.

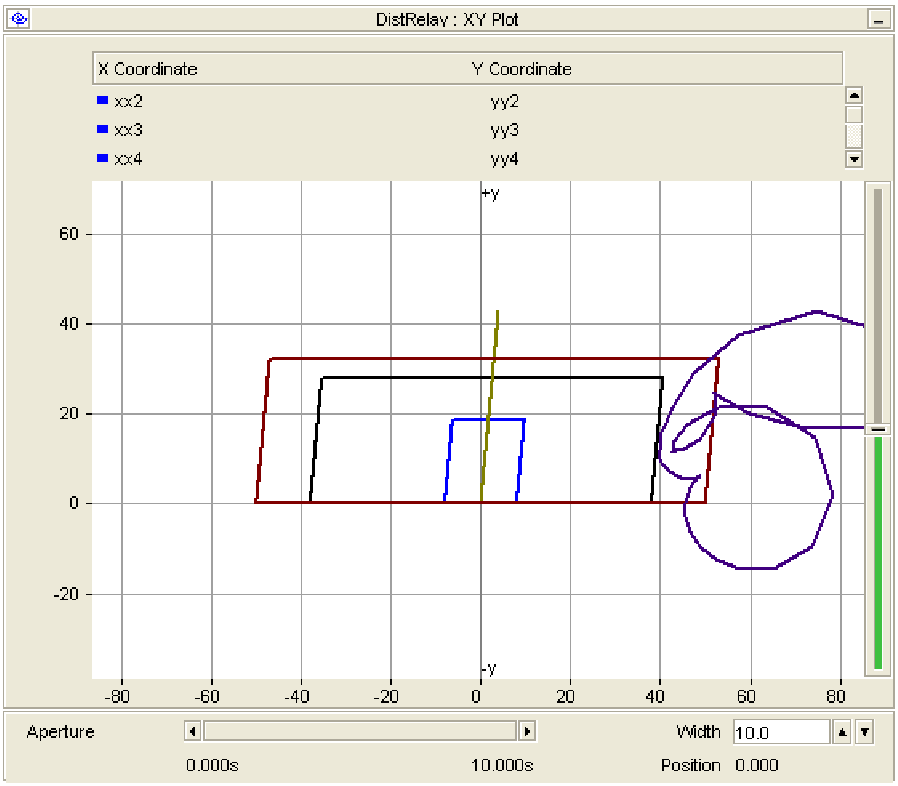

Figure 4.31: Quadrilateral Characteristics after fault at 110 kms with R_f = 78 Ω

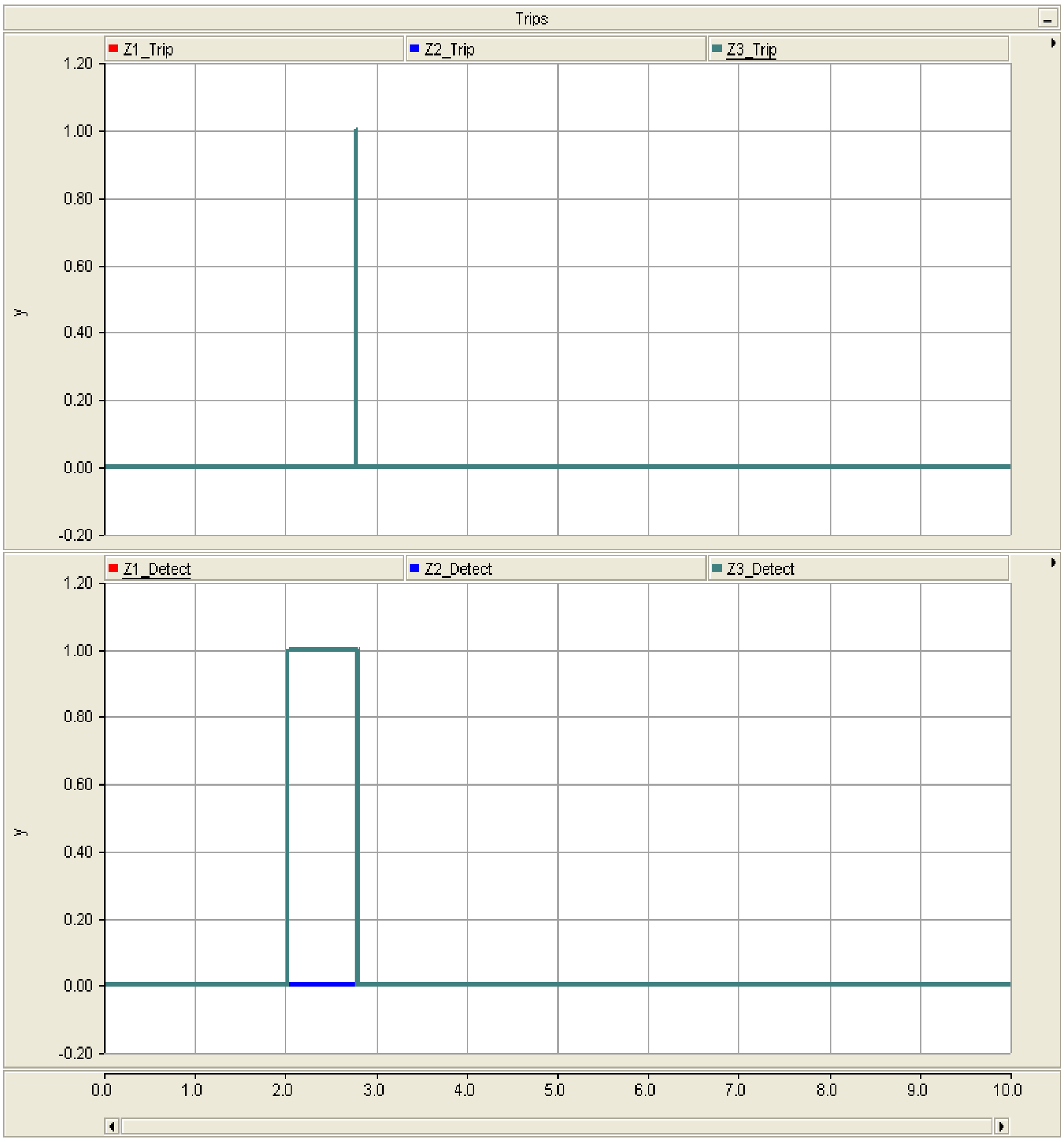

Figure 4.32: Trip during fault at 110 kms with $R_f = 78\ \Omega$

As shown in above figure 4.32, in below plot, we can see the duration for which the impedance enters different zones and in above lot, we can see the tripping signal.

Chapter 5

Power Swing

Power swings are caused by a lack of stability in the network with sudden load fluctuations. A power swing may cause the two sources connected by the protected line to go out of step (loss of synchronism) with each other. A power swing may cause the impedance presented to a distance relay to move away from the normal load area and into the relay characteristic. In the case of a stable power swing it is especially important that the distance relay should not trip in order to allow the power system to return to a stable conditions. For this reason, most distance protection schemes applied to transmission systems have a power swing blocking facility available[3].

5.1 Power Swing Detection and Blocking

The power swing detection element may be used to selectively prevent when the measured impedance point moves into the start-up characteristic from a power swing and still allows tripping for a fault (fault evolving during a power swing). The power swing detection element may also be used to selectively trip once an out-of-step condition has been declared.

Power swings are oscillations in power flow which can follow a power system disturbance. They can be caused by sudden removal of faults, loss of synchronism across a power system or changes in direction of power flow as a result of switching.

Such disturbances can cause generators on the system to accelerate or decelerate to adapt to new power flow conditions, which in turn leads to power swinging. A power swing may cause the impedance presented to a distance relay to move away from the normal load area and into one or more of its tripping characteristics[2].

A Power Swing is characterized by:

a. 3 successive impedance points in start-up zone of the biphase characteristic,

b. Slow variation of current,

c. Slow variation of voltage.

Power Swing detection uses a ΔR (resistive) and ΔX (reactive) impedance band which surrounds the entire biphase fault trip characteristic.

5.2 Resistive Reach

The load resietance is calculated as:

$$\begin{aligned} R_L &= \frac{0.8*(PT\ Primary)*1000}{\sqrt{3}*(Primary\ full\ load\ current)} \\ &= \frac{0.8*(400)*(1000)}{\sqrt{3}*(2000)} \\ &= 76.98\Omega(Prim.) \end{aligned} \tag{5.1}$$

$$\begin{aligned} R_{PH} &= 0.6*R_L*0.55 \\ &= 25.403\Omega(Secondary) \end{aligned} \tag{5.2}$$

$$\begin{aligned} R_G &= 0.8*R_L*0.55 \\ &= 33.871\Omega(Secondary) \end{aligned} \tag{5.3}$$

5.2.1 Phase Fault Resistive Reach Setting

The resistive reach setting lies between 4.8049 Ω and 25.403 Ω. Allowance should be made for the effects of any remote fault infeed, by using the maximum resistive reach possible. While each zone can have its own resistive reach setting, for this case they can all be set equal. This need not always be the case, it depends on the particular distance protection scheme used and the need to include Power Swing Blocking[3].

Suitable settings are chosen to be 80% of the load resistance:
$R3_{PH} = 25.403\,\Omega$
$R2_{PH} = 25.403\,\Omega$
$R1_{PH} = 25.403\,\Omega$

5.2.2 Earth Fault Resistive Reach Setting

The margin for avoiding the minimum load impedance need only be 20%. Hence the settings are:
$R3_{G} = 33.871\,\Omega$
$R2_{G} = 33.871\,\Omega$
$R1_{G} = 33.871\,\Omega$

5.2.3 Calculation of Power Swing Blocking

To avoid tripping during Power Swings, the limit of ΔR (resistive) and ΔX (reactive) are provided for the relay. For this purpose, Out-of-Step Relay block in PSCAD/EMTDC is used. Generally, the limits provided is 20% of R3PH for both ΔR and ΔX.

$$\begin{aligned} \Delta R &= 20\%\ of\ R3_{PH} \\ &= 0.2 * 25.403 \\ &= 5.08\,\Omega \end{aligned} \tag{5.4}$$

$$
\begin{aligned}
\Delta X &= 20\% \; of \; R3_{PH} \\
&= 0.2 * 25.403 \\
&= 5.08 \, \Omega \qquad (5.5)
\end{aligned}
$$

5.3 Simulation for Power Swing

For the simulation purpose of view, we have set the values of resistive reach equal for all the zones and provided 20% margin for Power Swing. Also, for transmission lines, tower structure with Remote Ends is used instead of using Direct Ends. The system with tower structure is as shown below in figure 5.1

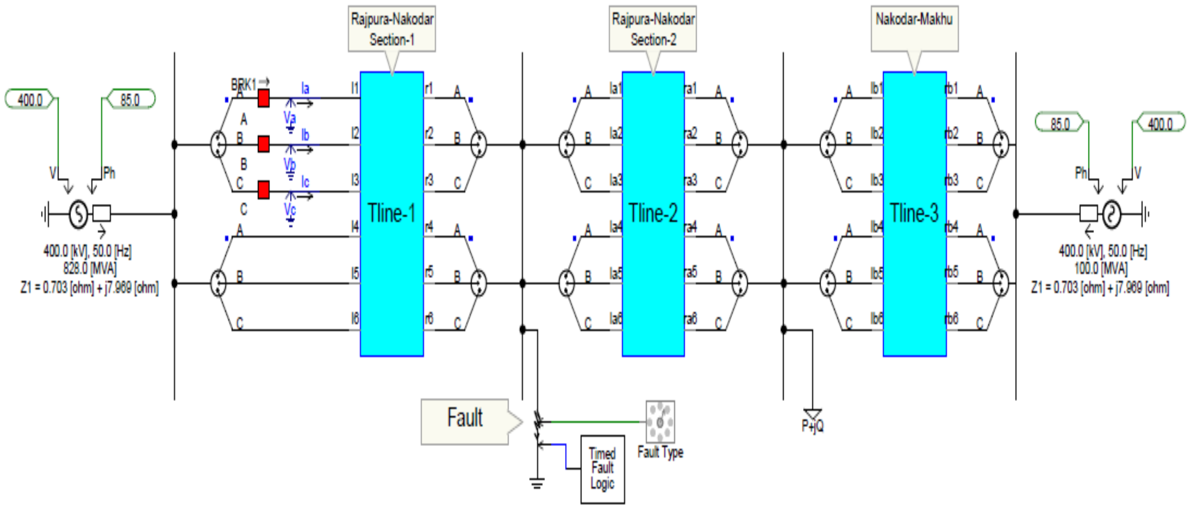

Figure 5.1: Single Line Diagram

The module of Tline-1 contains the remote ends connection to the tower as shown in figure 5.2. As it is seen, all the connection are collected with respective phases. Other logic for the protection system module will remain same instead of tripping logic. Here, during power swing, the relay should not operate.

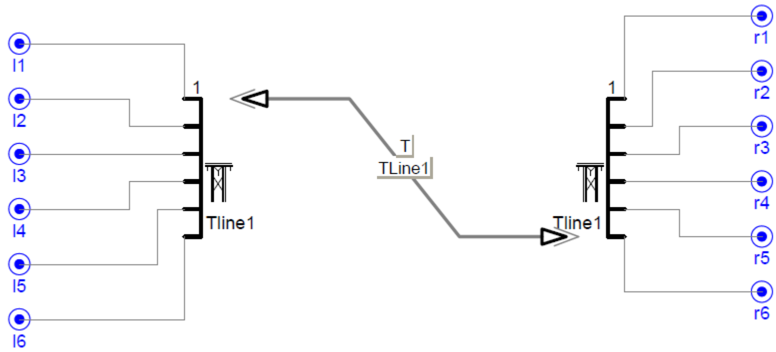

Figure 5.2: Transmission Line Module

5.4 Out-of-Step Relay

The Out-of-Step Relay Block of PSCAD/EMTDC is as shown below in figure 5.3. It is useful in detecting the Power Swing Condition and helps the protection system by not making it tripped during Power Swing.

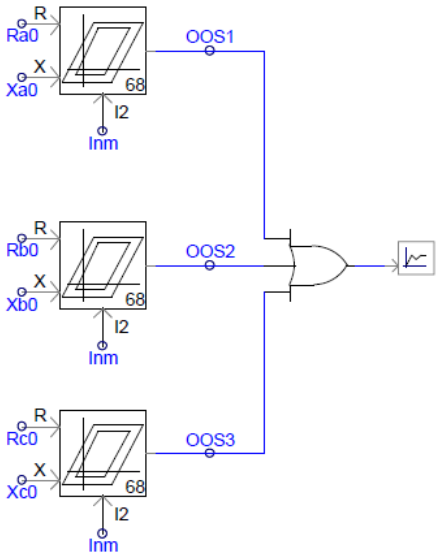

Figure 5.3: Out-of-Step Relay Block

When the impedance locus traverses from the outer power swing blocking zone 6 to the inner zone 5, Out Of Step (OOS) elements check the time taken to do so and if that is greater than a preset time, a power swing condition is detected. In most of the situations, distance relays should not operate to disconnect the associated circuit breakers, and tripping is required only at a few selected locations to perform system separation.

Blocking of trips from zone 1, zone 2 and zone 3 occurs when an impedance locus exceeds the preset time delay in traversing from zone 6 to zone 5, if the distance relay is not selected to perform a separating operation.

The output of 'OOS' elements can be used to block the trip from zone 1, zone 2 and zone 3 distance elements during power swing conditions, or to trip the circuit breakers at a selected location where is designed to separate a power system from an unstable system.

R and X represent the resistive and reactive parts of the monitored impedance, and may be input in per-unit or ohms. The I_2 input represents the negative sequence current and may be input in per-unit or kA. Please note however, that the units of the component input parameters should match that of the R, X and I_2 inputs respectively. The component produces an output '1' if a power swing condition is detected, otherwise the output will be '0'.

Here zones 5 and 6 are defined as quadrilaterals (polygons). In addition to the impedance locus traversing from zone 6 to zone 5 taking more than the specified preset time, the negative sequence current I_2 must also be less than the restraint current for a blocking signal to be produced.

5.5 Tripping Logic

As shown in figure 5.4, we can see the tripping logic for the system.The upper part will detect whether the faulty impedance is in the predefined zones. If it is seen, it will check the condition if it sustain for the defined delay time and accordingly it sends the trip signal.

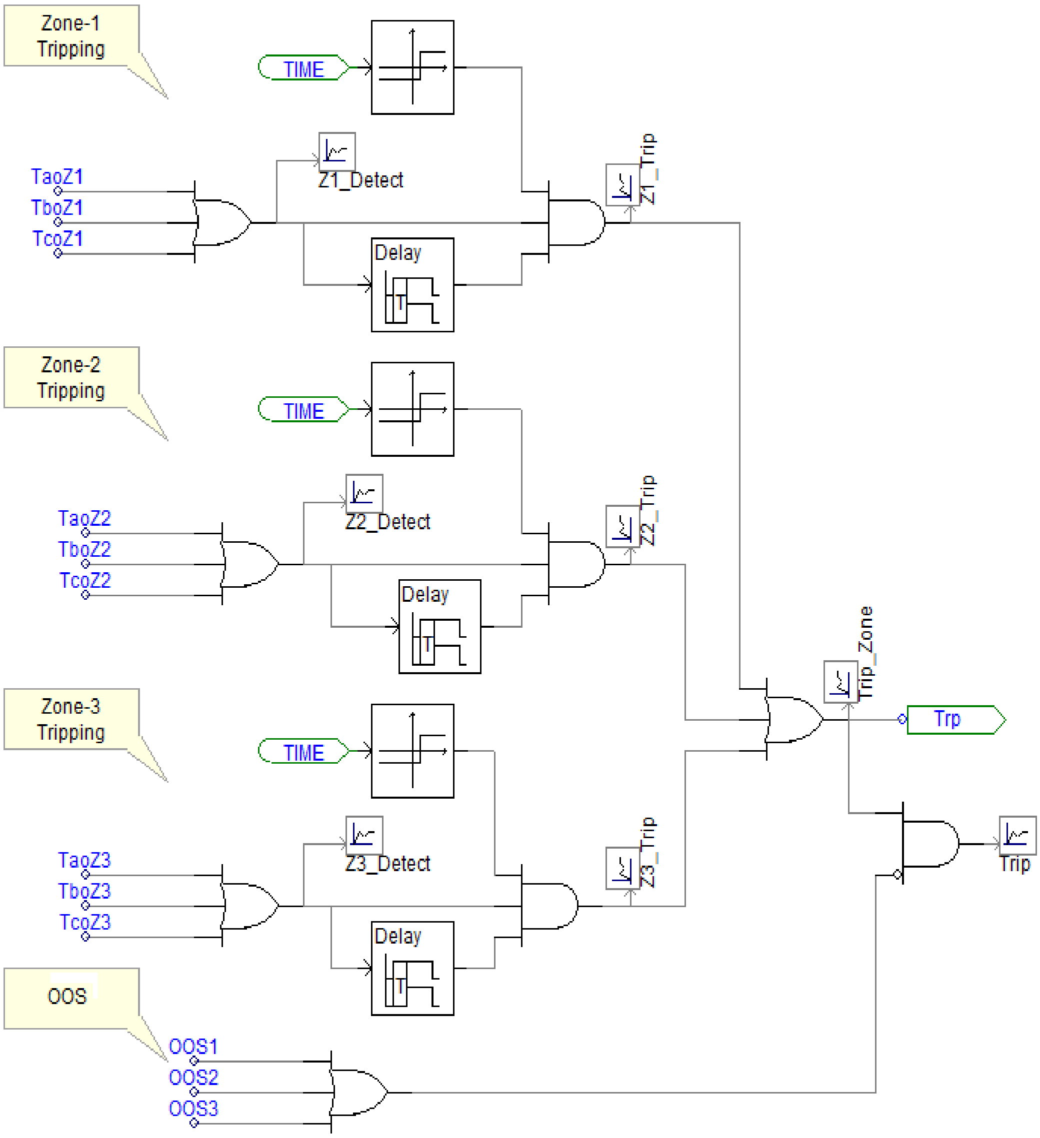

Figure 5.4: Tripping Logic

The lower part is for power swing detection. If the power swing is seen in the defined zone, it will be detected by Out-of-Step relay block.

5.6 Simulation Results for Power Swing

5.6.1 Case-1

When Single Line-Ground fault is created at 100 kms for 0.03 seconds, the Quadrilateral characteristics looks like:

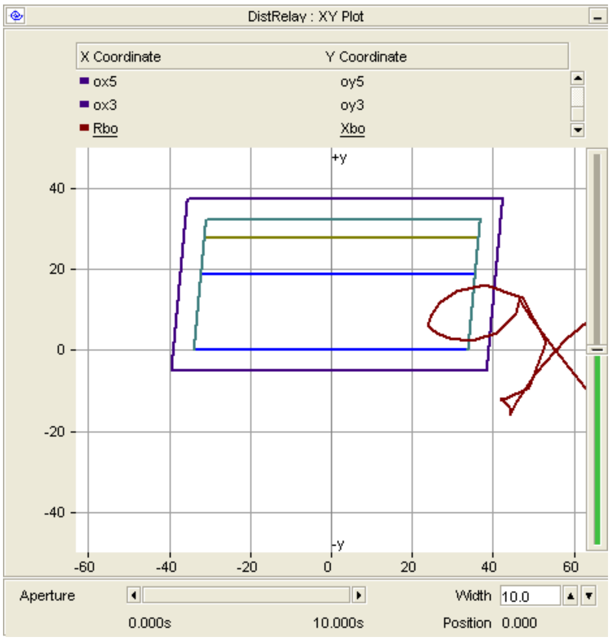

Figure 5.5: Quadrilateral characteristics when fault is created at 100 kms

As shown in figure 5.5, the fault was created at 100 kms with fault resistance 10Ω and the duration of fault was set to 0.03 seconds. The fault was applied after 2 seconds. Inner boundary is for zone wise reaches and outer boundary is for Power-Swing detection.

In figure 5.6, if the impedance enters the zone reach, trip-zone will show the duration for which the impedance remains in the zone and OOS will show the duration for which out-of-step condition is detected and trip will show the total tripping signal.

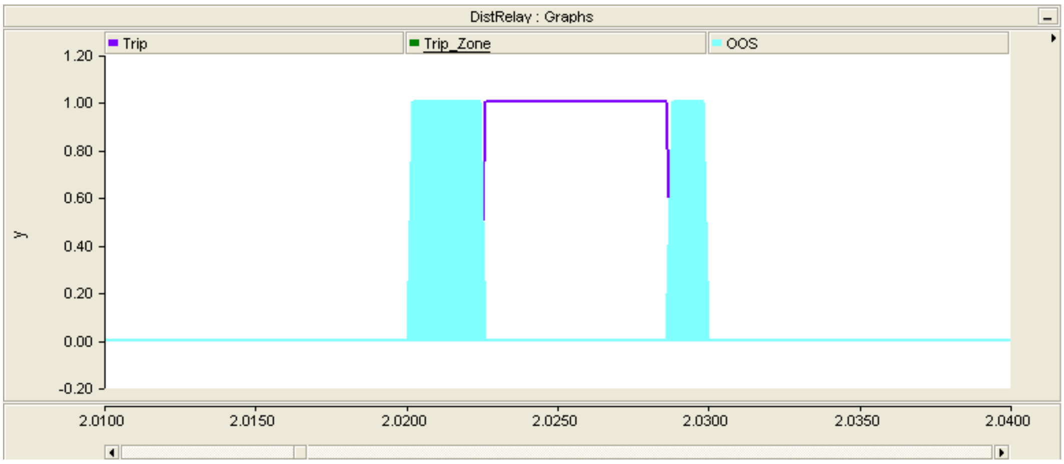

Figure 5.6: Tripping Logic when fault is created at 100 kms

5.6.2 Case-2

When Single Line-Ground fault is created at 100 kms for 0.03 seconds, the Quadrilateral characteristics looks like:

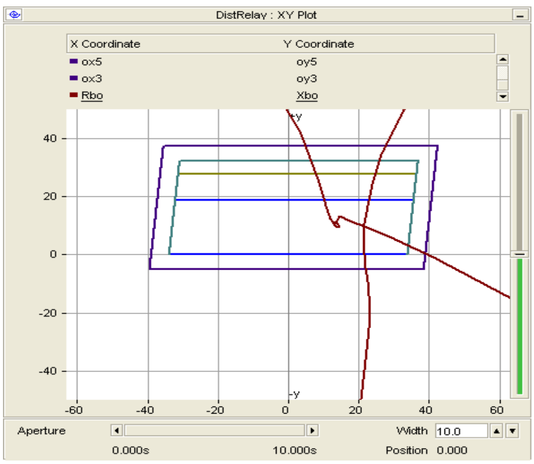

Figure 5.7: Quadrilateral characteristics when fault is created at 100 kms

As shown in figure 5.7, the fault was created at 100 kms with fault resistance 15Ω and the duration of fault was set to 0.03 seconds. The fault was applied after 2 seconds. Inner boundary is for zone wise reaches and outer boundary is for Power-Swing detection.

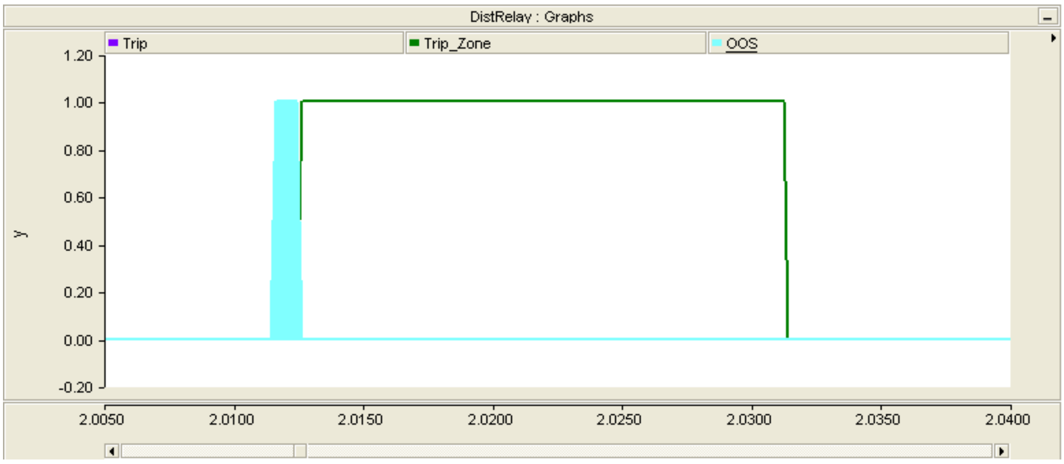

Figure 5.8: Tripping Logic when fault is created at 100 kms

As shown in figure 5.8, if the impedance enters the zone reach, Trip-Zone will show the duration for which the impedance remains in the zone and OOS will show the duration for which Out-of-Step condition is detected and Trip will show the total tripping signal.

5.6.3 Case-3

When Single Three Phase fault is created at 75 kms for 0.1 seconds, the Quadrilateral characteristics looks like:

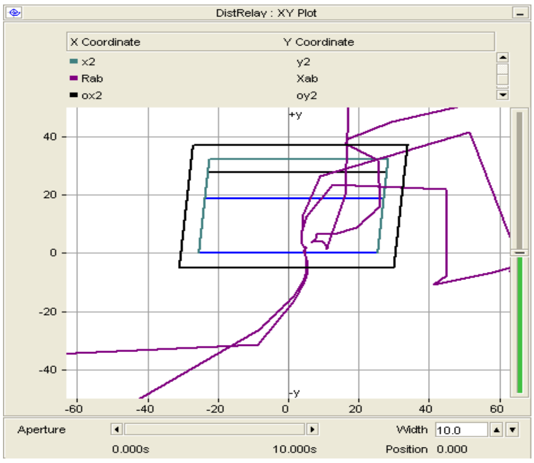

Figure 5.9: Quadrilateral characteristics for A-B when L-L-L fault is created

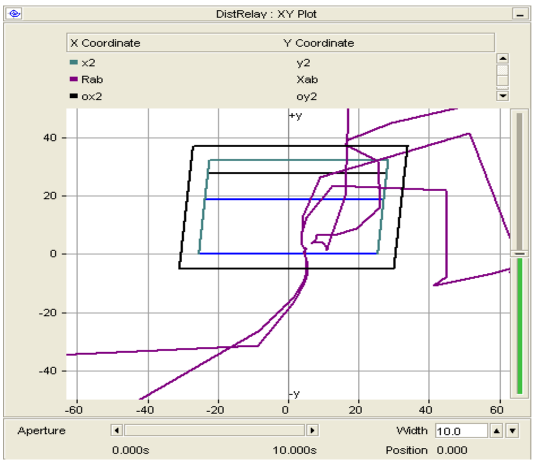

Figure 5.10: Quadrilateral characteristics for B-C when L-L-L fault is created

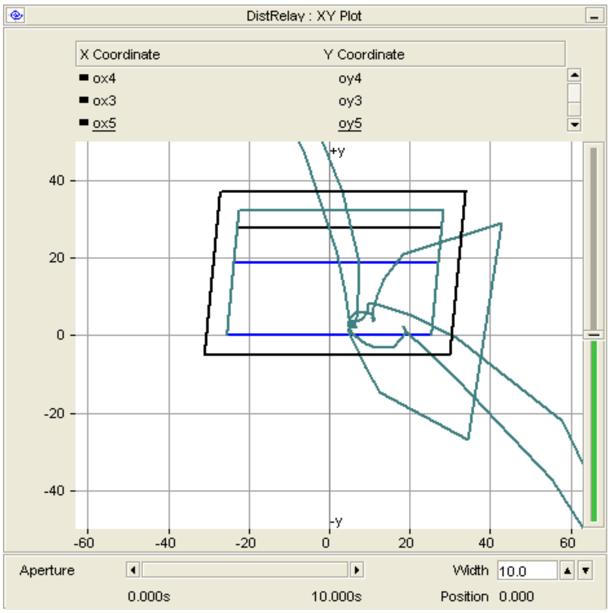

Figure 5.11: Quadrilateral characteristics for C-A when L-L-L fault is created

Figure 5.9, 5.10 and 5.11 shows the Quadrilateral characteristics when the three phase fault was created at 75kms with fault resistance 10Ω and the duration of fault was set to 0.1 seconds. The fault was applied after 2 seconds. Inner boundary is for zone wise reaches and outer boundary is for Power-Swing detection.

Figure 5.9 shows the fault impedance due to phase A and B, figure 5.10 shows the fault impedance due to phase B and C whereas figure 5.11 shows the fault impedance due to phase C and A. All the three phase-phase impedance can be seen clearly entering the characteristics.

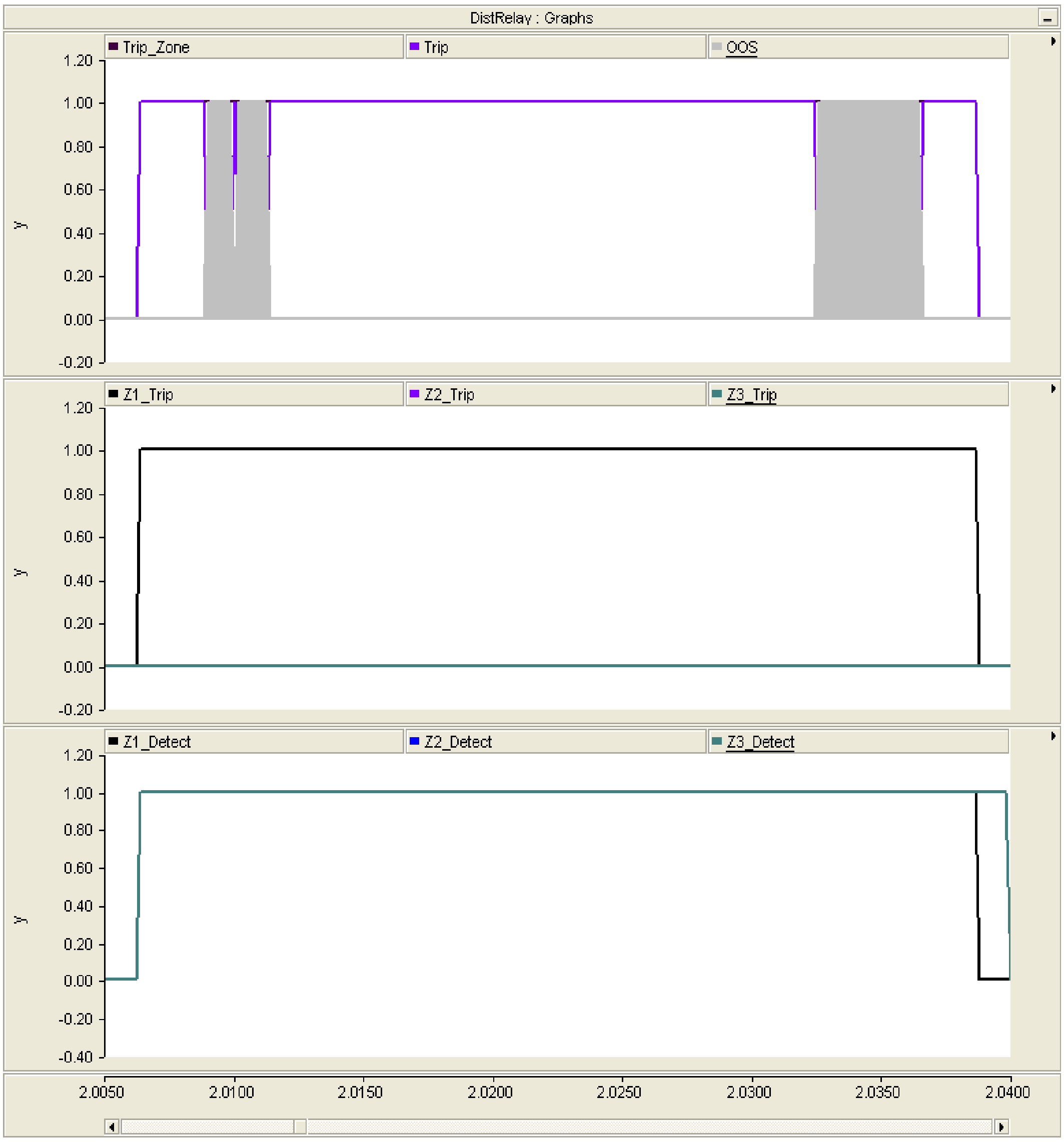

Figure 5.12: Tripping Logic when L-L-L fault is created at 75kms

As shown in figure 5.12, if the impedance enters the zone reach, Trip-Zone will show the duration for which the impedance remains in the zone and OOS will show the duration for which Out-of-Step condition is detected and Trip will show the total tripping signal.

Chapter 6

Conclusion and Scope of Work

6.1 Conclusion

Distance Protection system operates according to zone-wise characteristics. First, the calculations for Distance Protection were done for Rajpura TPPS-Nakodar line. Based on that calculations, modelling was developed using PSCAD/EMTDC software. The MHO characteristics was developed and then was simulated at different locations for different faults. The behaviour of MHO characteristics during different faults was observed. The effect of arc resistance on MHO characteristics was also observed. Due to fault resistance, it can be concluded that the MHO relay under-reaches. The same system was then simulated by developing Quadrilateral characteristics and different faults were applied at different locations. Quadrilateral characteristics is more effective than MHO characteristics because of its behaviour as the resistive and reactive reaches can be set independently. At last, Power Swing was introduced in the system and it can be observed that the relay does not operate during Power Swing.

6.2 Scope of Work

The simple Quadrilateral characteristics has been developed using PSCAD/EMTDC software. The Quadrilateral characteristics with directional feature can be developed for better operation. Here, the residual compensation factor was selected as equal for all the zones but this may not be the case always. Also, the TILT angle protection can be developed as well. TILT angle protection can only be applied with conventional protection.

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