International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Performance Assessment of Distance Relay using MATLAB

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Abstract

This paper studies the performance of distance relay using MATLAB. Different fault cases L-G (Single Line to Ground), L-L (Single Line to Line), and Three phase faults were taken and the R-X diagram or the Mho characteristic was used to study the performance of the relay, along with the trip time calculation. The effect of fault resistance on relay performance has been studied. This paper lays down the basic framework to study the modern communication based distance protection systems.

Keywords - Distance Relay, Fault System, MATLAB.

1. Introduction

Energy is a fundamental requirement for the economic sustenance of any country. A Power System is a network of electrical components used to supply, transmit and use electric power. A fault in the power system is a condition when an abnormally large amount of current flows through the system. Power system protection aims at protecting this system from fault conditions, to ensure the smooth generation, transmission and distribution of this essential form of energy. The Distance Relay is one of the relays used for this purpose, and is connected mainly with the transmission system. Performance of the distance relay varies with fault resistance and fault location.

1.1. Relay Performance Characteristic

The performance of a Distance Relay can be assessed with a number of performance characteristics such as the mho, quadrilateral, reactance, admittance, polarised-mho, offset mho etc. We have used the mho characteristic or the R-X diagram here [1].

The Figure 1 shows an R-X diagram created in MATLAB for our assessment purpose. This is for a relay with two protection zones. Z1 is the reach setting of zone 1, and Z2 is the reach-setting of zone 2. [2]

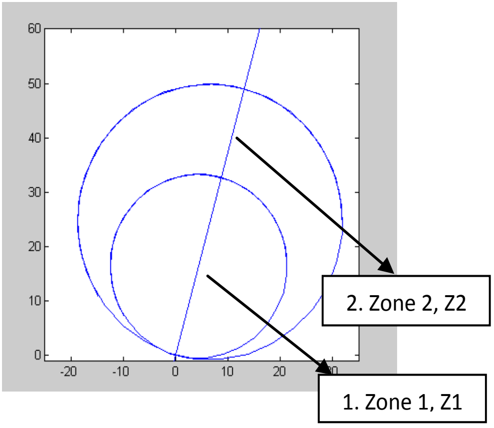

Figure 1: R-X diagram

1.2. Relay Trip Time

The trip is the interval between fault detection and the time the protection circuit is triggered or the relay trips.

1.3. Fault Calculation Algorithms

The fault calculation algorithm used depends on the type of the fault that occurs. The line to line (LL) fault, double line to ground (DLG) fault and single line to ground (SLG) fault are classified as unsymmetrical faults. Three phase fault is the only symmetrical fault where all phases are in contact with each other.
The distance Relay will first determine the type of fault with the help of a fault current magnitude detection algorithm. After that, the corresponding formula is used for fault impedance calculation.

TABLE 1: Fault impedance calculation formulae for different faults

Fault Type	Algorithm
AG	VA/(IA+3k0I0)
BG	VB/(IB+3k0I0)
CG	VC/(IC+3k0I0)
AB or ABG	(VA-VB)(IA-IB)
BC or BCG	(VB-VC)(IB-IC)
CA or CAG	(VC-VA)(IC-IA)

Where;
A, B and C indicates faulty phases.
G indicates ground fault.
VA, VB and VC indicate voltage phasors
IA, IB and IC indicate current phasors
Z0 = line zero-sequence impedance
Z1 = line positive-sequence impedance
k0 = residual compensation factor where k0 = (Z0-Z1)/kZ1. k can be 1 or 3 depend on the relay design.

2. Problem Definition

The main aim of our project was to execute a performance assessment of distance relay using MATLAB SIMULINK. The basic steps involved in our project:

1. Design a power system in SIMULINK using the SimPowerSystem Blockset with proper parameters for each component block.
2. Design the signal processing and distance relay subsystems (anti-aliasing filters, A/D conversion, digital filters, Discrete Fourier Transform etc.)
3.Construct a fault detection and trip time calculation algorithm for different faults.
4. Construct a mechanism to obtain the R-X diagram of the relay with proper parameters and protection zones
5. Study the performance of the distance relay system and program with the help of R-X trajectories for various faults.
6. Study the effects of fault resistance on distance relay performance.

3. Methodology

3.1 Designing the Power System

The power system for simulation purposes has been designed in MATLAB SIMULINK (Figure 2). The SimPowerSystem provides the necessary components to model the power system. The system designed is symmetric double sourced system. Each of the components of the three phase currents and voltages are obtained with the help of current transformers (C.T) and voltage transformers (V.T) respectively. The components are sent to the relay subsystem, which filters the high frequency harmonic components.
The relay model has been designed and connected with the main power system model with the help of the subsystem tool in SIMULINK. This makes the overall model compact and easy to observe during analysis

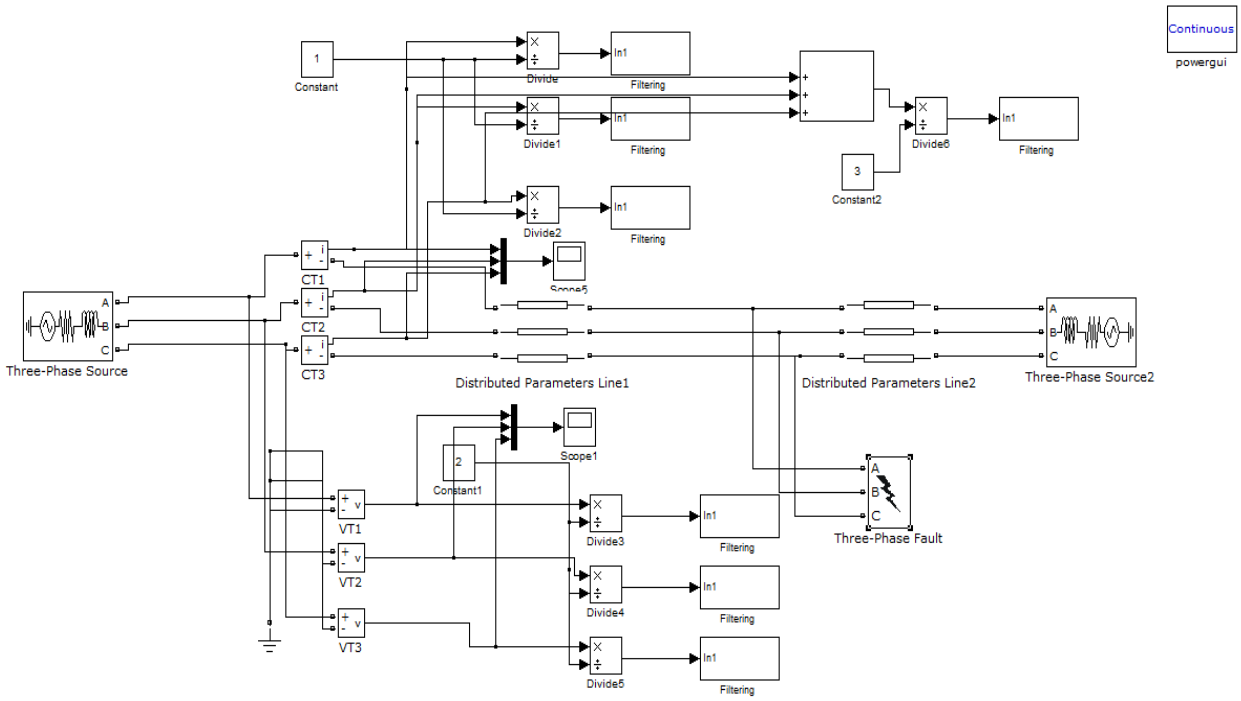

FIGURE 2: SIMULINK model of the power system

TABLE 2: Model parameters 1

Three phase source block 1		
	Value	**Unit**
Power system voltage	132,000	Volt
Phase angle of phase A	15	degree
Nominal frequency	50	Hz
Source Resistance	0.238	Ohms
Source Inductance	0.00182	Henry
Distributed line parameters block 1		
Line length	75	km
Positive sequence resistance	0.0275	Ω/km
Zero sequence resistance	0.275	Ω/km
Positive sequence inductance	0.001345	H/km
Zero sequence inductance	0.003725	H/km
Positive sequence capacitance	9.483e-9	F/km
Zero sequence capacitance	6.711e-9	F/km

TABLE 3: Model parameters 2

Three phase source block 2		
	Value	**Unit**
Power system voltage	132,000	Volt
Phase angle of phase A	0	degree
Nominal frequency	50	Hz
Source Resistance	0.238	Ohms
Source Inductance	0.00182	Henry
Distributed line parameters block 2		
Line length	25	km
Positive sequence resistance	0.0275	Ω/km
Zero sequence resistance	0.275	Ω/km
Positive sequence inductance	0.001345	H/km
Zero sequence inductance	0.003725	H/km
Positive sequence capacitance	9.483e-9	F/km
Zero sequence capacitance	6.711e-9	F/km

3.2. Designing the Subsystem.

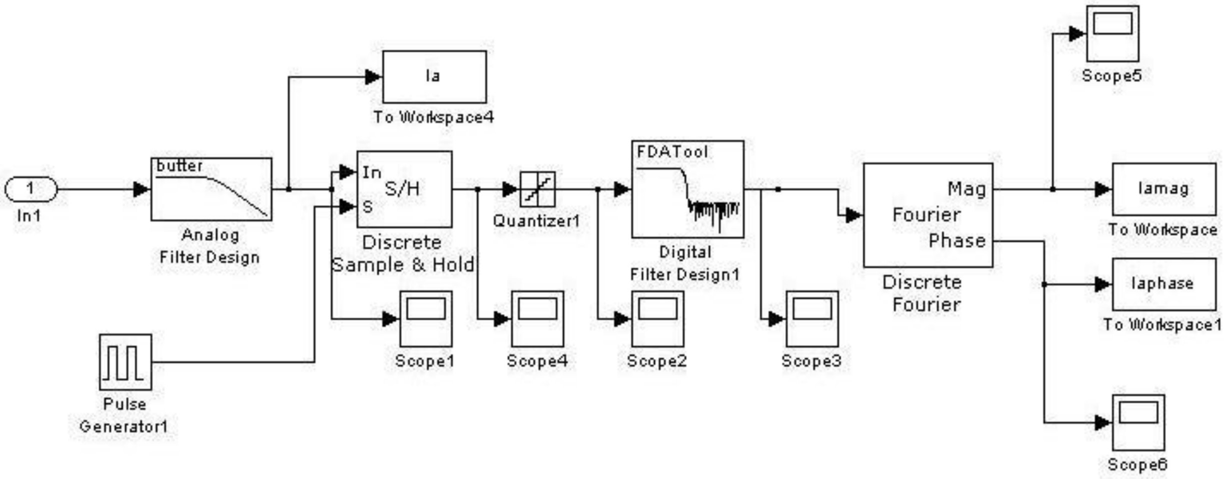

FIGURE 3: SIMULINK sub-system model

There are six filtering subsystems in the main power system model. These process the faulted signals and obtain the phasors of the fundamental components of the voltage and current signals, which we later use to plot the performance characteristic of the relays.

4. Results

4.1. R-X plots for different fault cases

One example for Line to Ground and Line to Line type of fault is considered, and fault resistance is Rf=5ohm:

4.1.1 L-G fault (Line to Ground fault)

Phase A to Ground Fault (A-G fault)
Trip time = 14.1ms

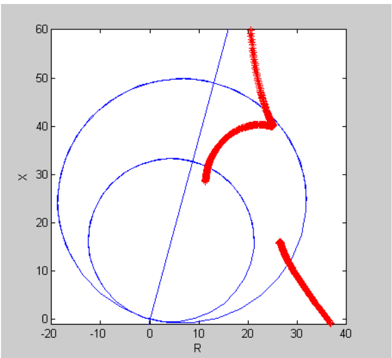

Figure 4: R-X plot for A-G fault with Rf=5ohm

4.1.2 Line to Line faults (L-L faults)

Phase B to phase C fault (A-B fault)
Trip Time = 14.2ms

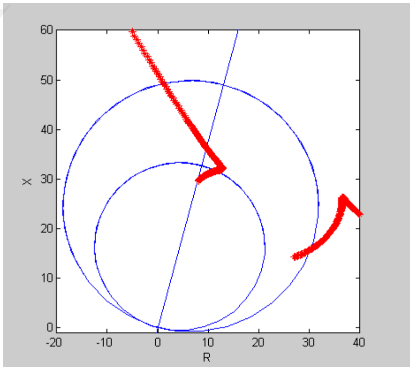

Figure 5: R-X plot for B-C fault with Rf = 5ohm

4.2. Variation of relay performance with change in fault resistance

The change in fault resistance will lead to variation in the R-X trajectory of the relay. This translates to a change in the trip time and the relay performance is thus affected.

The L-L fault case (specifically phase B to phase C) has been considered to show the effect of fault resistance (Rf) on relay performance. The case for 5ohm fault resistance has already been shown in figure 5.Now, with Rf=15 ohm and Rf=25ohm, we have:

4.2.1. Rf = 15ohm

Trip time = 19.2ms

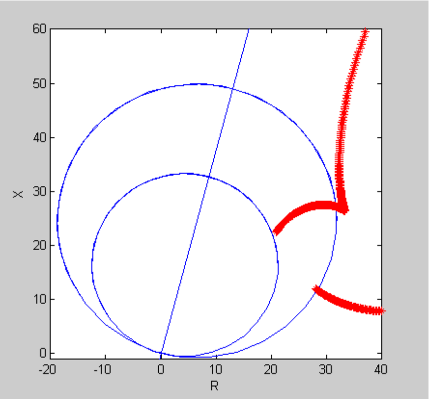

Figure 6: R-X plot for B-C fault with Rf = 15ohm

4.2.2. Rf = 25ohm

The fault does not enter zone 1 when Rf=25ohms.

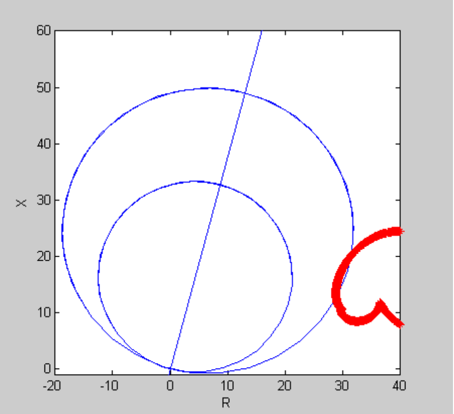

Figure 7: R-X plot for B-C fault with Rf = 25ohm

5. Conclusions

The fault impedance trajectories have been studied and verified on the relay R-X diagrams for the various fault cases in MATLAB environment. The variation in fault resistance affects the performance of the distance relay.

6. Future Scope of Work

With the advent of advanced communication based protection systems and digitization of distance relay, digital samples are often lost in the communication system. Algorithms can be developed to estimate the missing samples and obtain the correct fault trajectories despite thelost samples. Further research can be made in this area building upon our work.

7. References

[1] MuhdHafiziIdris, Surya Hardi and MohdZamriHasan, “Teaching Distance Relay Using Matlab/Simulink Graphical User Interface”, University Malaysia Perlis, Kuala Perlis, Malaysia

[2]Dr. Hamid H. Sherwali and Eng. Abdlmnam A. Abdlrahem, “Simulation of Numerical distance relays”, Al-Fatah University, Tripoli-Libya.