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ANALYSIS OF DISTANCE RELAY PERFORMANCE IN PROTECTION OF HIGH VOLTAGE TRANSMISSION LINE

A.M. Purohit
Department of Electrical Engineering,
MIT College of Engineering,
Pune, Maharashtra State.

V.N. Gohokar
Department of Electrical Engineering,
AISSMS College of Engineering,
Pune, Maharashtra State.

Abstract
Growing demand of electrical energy leads to the increasingly complex nature of electrical power systems. Protection of transmission lines plays crucial role in improving the reliability of power system as well as to restore the services of power utilities. As transmission lines are frequently subjected to various kinds of faults different protection schemes are evolved for the effective protection of transmission lines. Distance protection is the most widely used protection system in case of high voltage and extra high voltage transmission lines. Understanding the operation of distance relay involves complex theories and philosophies. The effective use of MATLAB/SIMULINK package helps in clearly understanding the behaviour of distance relay in protecting the transmission lines under abnormal conditions.This paper focuses on modelling and simulation of distance relay using MATLAB/SIMULINK package.In this paper, distance relay is connected to a 230 kV interconnected system with 400kv transmission line. The simulation results illustrate the simple and effective way to study the relay protection in power system.

Keyword- Power System; Distance protection; Apparent Impedance; MATLAB/SIMULINK; Graphical User Interface

I. INTRODUCTION

Due to increasing population and industrialization electrical power demand is continuously increasing and also due to integration of power grids electrical power systems are becoming complex in nature and configuration. It is necessary to develop new techniques to tackle the challenges of these complex power systems, especially protection of power systems. Protection of transmission lines plays crucial role in improving the reliability of power system as well as to restore the services of power utilities.[1][2]Transmission lines are prone to various types of faults. They can be classified as phase and ground faults, permanent faults, transient faults, semi transient faults and simultaneous faults**.[3]**Phase faults and ground faults are the faults involving more than one phase with or without ground. Faults involving any phase with ground are called ground faults. Thus a power system has to tackle a total of ten types of phase and ground faults. [1-3] Permanent faults are created by puncturing or breaking insulators, breaking conductors and objects falling on the ground conductor or other phase conductors. These faults are detected by relays and trip the circuit breakers which remains locked out. Transient faults are of short duration and are created by transient over voltages. Basically, this fault is caused by a flashover across the insulation due to abnormal transient over voltages. Semi transient faults are created by external objects such as a tree branch or rodent. In medium voltage lines a multishot automatic CB reclosure can burn out the object causing a fault, restoring the equipment and improving supply reliability. Simultaneous faults such as flashover faults to ground, cross country faults and open conductor and ground faults are the faults which occur either at same or different locations on double circuit lines. There are various causes for faults on transmission lines. If healthy insulation in the equipment is subjected to either transient overvoltage of small time duration due to switching and lighting strokes, direct or indirect. This causes failure of insulation, resulting in fault current or short circuit current. Another cause of faults is insulation aging which may cause breakdown even at normal power frequency voltage. If an external object, such as a tree branch, bird, kite string, rodent etc. spanning either two power conductors or a power conductor and ground causes fault on transmission lines. Statistically about 80% of faults are transient and 20% are permanent.[1-3]the majority of L-G faults are transient or arcing faults. No relaying scheme can, by itself, detect whether a fault is transient or permanent. So it is necessary to see that lines are not disconnected unnecessarily and also shorter operating times for relays. This demands utmost accuracy and reliability of protective systems. Due to advent of computing and communication systems protective relays have evolved relays from electromechanical relays to the processor based numerical relays. This has resulted into more accurate and reliable performance of the protective relays over faster and faster relays.

This paper presents the modelling of distance relay using MATLAB/ SIMULINK package. Sim Power system toolbox is used for detailed modelling of distance relay, transmission line, and fault simulation.

II. DISTANCE RERAY PROTECTION SCHEME FOR TRANSMISSION LINES

Distance protection is the most popular and widely used protection in power networks as the main and backup protection of transmission lines due to its advantages like suitability, simplicity, economy and reliability. [1-3]The measured impedance at the relaying point is the main principal

Paper ID: EE01

of operation distance relay protection scheme. Conventional distance relay consists of three measuring units, can be three separate units or one unit for the first and second zone with time delay and a second unit for the third zone. The first and second unit act as primary protection units whereas second and third zone provides remote back up protection for adjacent lines. Distance relay has different types of characteristics depending upon its function and principal used such as mho, polarised mho, offset mho, reactance, and admittance etc. [4] Mho type of distance relay is used for simulation purpose in this scheme. Figure1 shows the characteristics of Mho distance relay along with its protection zones which is generally used for protection of high voltage and extra high voltage long transmission lines.[3]

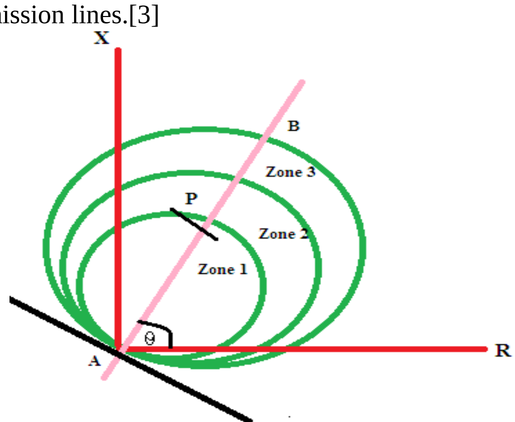


Figure1Mho Type Distance Characteristics

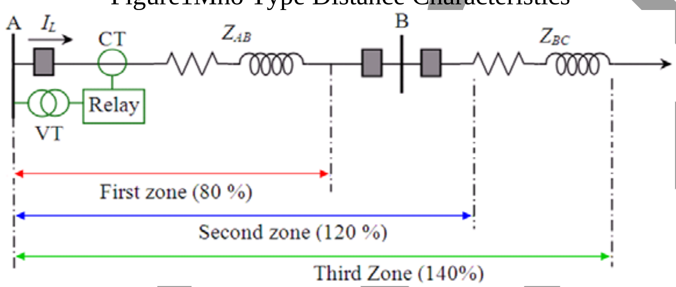


Figure 2 Zones Setting Of Distance Relay

III. IMPEDANCE MEASUREMENT ALGORITHM

Basically faults in a power system are classified as symmetrical faults and unsymmetrical faults. Three phase fault is the only symmetrical fault while all other faults like line to line fault (LL), double line to ground fault (DLG), and single line to ground fault (SLG) lie under the category of unsymmetrical faults. Distance relay operation is based on measuring the impedance between faulty phases in case of LL fault or between faulty phase and ground in case of ground fault. Table 1 show the different algorithm used to calculate the fault impedance for various types of fault taking place in transmission lines. [4-10]

Table1. FAULT IMPEDANCE MEASUREMENT ALGORITHM FOR VARIOUS TYPES OF FAULT

Type of Fault	Algorithm
ABC or ABCG	(VA/IA) or(VB/IB) or(VC/IC)
AB or ABG	(VA-VB)/ (IA-IB)
AC or ACG	(VA-VC)/ (IA-IC)
BC or BCG	(VB-VC)/ (IB-IC)
AG	(VA)/ (IA+3koIo)
BG	(VB)/ (IB+3koIo)
CG	(VC)/ (IC+3koIo)

Where:
A, B, C indicates faulty phases, G indicates ground fault.
VA, VB, VC indicate voltage phases
IA, IB, IC indicate current phases
Z0 = line zero sequence impedance
Z1 = line positive sequence impedance
Ko= residual compensation factor where Ko= (Z0- Z1)/ K Z1.K can be 1 or 3 depending on relay design.
Io= (Vs/ Zo + 2 Z1)
Where Vs is phase voltage during the phase to ground fault

IV. DISTANCE RELAY MODELLING

Operation of the relay can be realized in a better way using software relay models. Modelling of the protective relay is a powerful tool to understand the operation of the relay in an economical and effective way. MATLAB/SIMULINK is a powerful software package which has an ability of modelling, simulating and analysing the performance of various power system components like three phase load, three phase transformer, circuit breaker, transmission line parameters etc. used for various AC and/or DC applications. Wide selection of libraries available in SimPowerSystems toolbox inside SIMULINK package helps in detailed simulation of protective relay. Various aspects of digital relaying like signal conditioning, analog to digital conversion, filtering, phasor estimation, implementing algorithms and finally relay trip logic can be simulated in an effective manner using different general and special purpose blocks from the signal processing block sets.

This paper focuses on developing the model for distance relay. Performance of the developed relay is analysed for single fed transmission line under normal as well as under fault condition. For faulty phase detection and apparent impedance calculation post fault three phase voltages and current phasors are

Paper ID: EE01

required. Low pass filter is used to extract fundamental components of three phase voltages and currents available from VT and CT respectively. These fundamental components of three phase voltages and currents are then given to the FFT block which helps to extract the magnitudes and phase angle from these fundamental phasors. FFT block set is used to perform a Fourier analysis of the input signal over a running window of one cycle of the fundamental frequency of the input signal. These magnitudes are then given to the Fault Measurement block for impedance calculation of the faulty phase. The outputs of this block are the magnitudes of resistance and reactance and also the magnitudes and phase angles of impedance. All these values are calculated for pre fault as well as for post fault condition.

V. MODELS FOR MEASURING APPARENT IMPEDANCE

Figure 3 and Figure 4 represents the model developed using SIMULINK package for calculation of a single phase to ground and double phase to ground fault. [5]

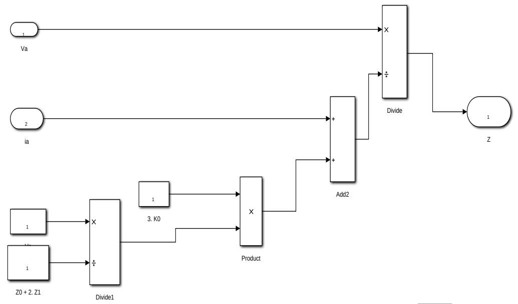


Figure 3.Apparent Impedance for SLG fault

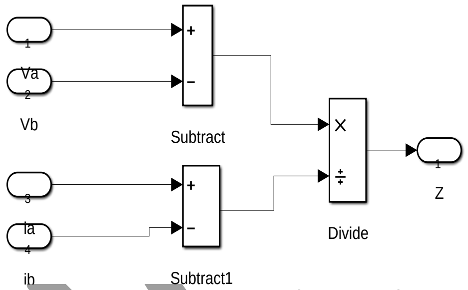
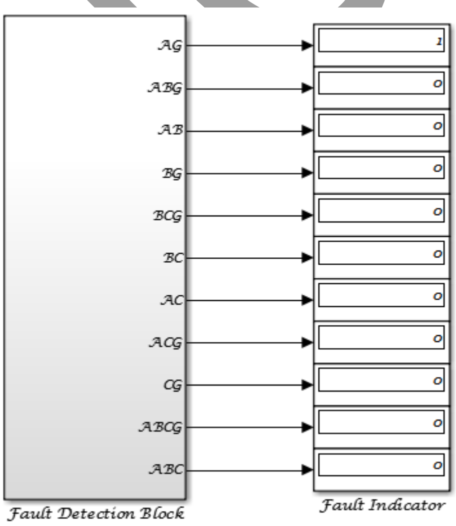


Figure 4.Apparent Impedance for DLG fault



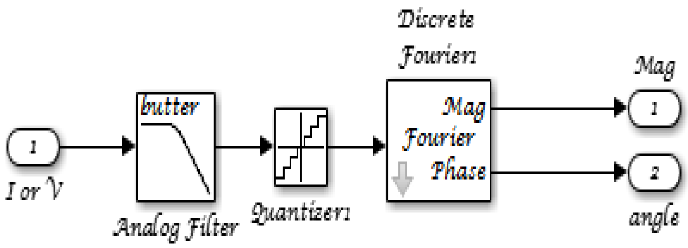


Figure5. Modelling Of Transmission Line and Three

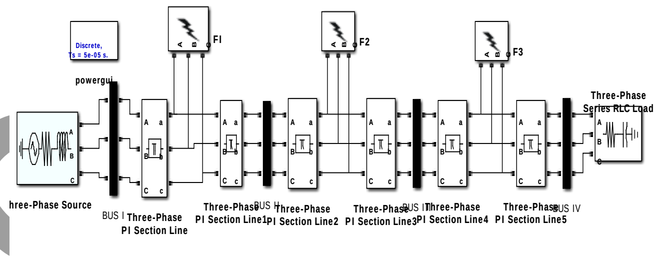


Figure 6. Developing Of Distance Relay Model

Current and voltage waveforms obtained from instrument transformers are scaled down and passed through low pass filter which helps to eliminate the effects of noise and unwanted component of frequencies. Each analog input signal is applied to the sample and hold circuit and then it is conveyed to the Analog to Digital converter. The effect of Quantizer is to quantize a smooth signal into a stair-step output. Discrete Fourier Transform is used to remove the dc-offset components. DFT computes the magnitude and phase at discrete frequencies of a discrete time sequence. Figure 8.Fault Detection Model Phase A to ground fault output (AG fault)

VI. SIMULATION PARAMETERS

The network used for study consists of one three phase power supply as a power station. The power station is supplying 400kv transmission line. Three separate transmission lines each 100km, is designed to deliver the three phase load at the end of the transmission line. The bus bars are provided with an arrangement of voltage and current measurement.

The relay model developed using SIMULINK is integrated with the power system model. Performance of the distance relay is analysed under normal and under fault condition. The parameters of the Power System, Transmission Line and Load are listed in Table II.

Paper ID: EE01

Table II. POWER SYSTEM, TRANSMISSION LINE AND LOAD PARAMETERS

Power System, Transmission Line And Load Parameters	Value	Unit
Power System		
Power System Voltage		Volt
Phase angle of phase A	0	Degree
Nominal frequency	60	Hertz
3 phase short circuit level at base voltage		
Source X/R ratio	7	-
Transmission line		
Line Length(L), T.L.1=T.L.2= T.L.3	100	Km
Positive sequence resistance	0.01165	Ω/ Km
Zero sequence resistance	0.2676	Ω/ Km
Positive sequence inductance	$0.8679e^{-3}$	H/ Km
Zero sequence inductance	$3.008e^{-3}$	H/ Km
Positive sequence capacitance	$12.7e^{-9}$	F/ Km
Zero sequence capacitance	$7.751e^{-9}$	F/ Km
3 Phase load		
Active Power	40,000,000	W
Inductive Reactive Power	0	Var
Capacitive Reactive Power	19,373,000	Var

VII. SIMULATION RESULTS

Single line to Ground Fault (AG Fault)

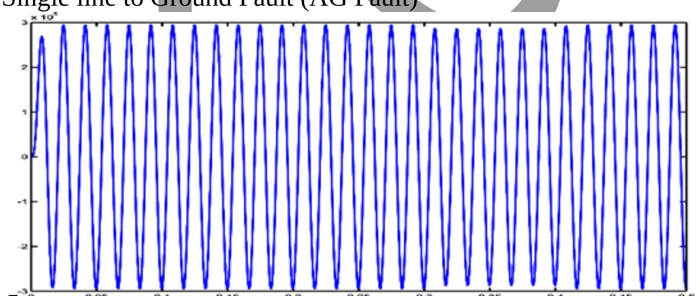


Figure 9.Voltage signals as appeared after Analogue to Digital Converter

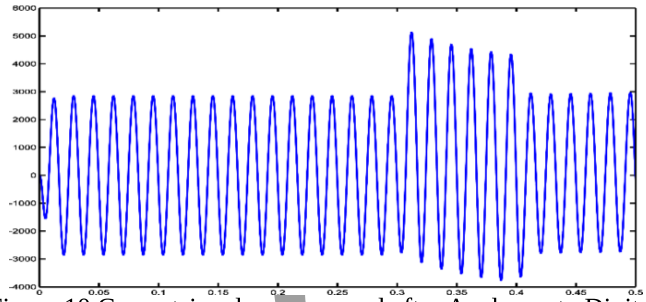


Figure 10.Currentsignals as appeared after Analogue to Digital Converter

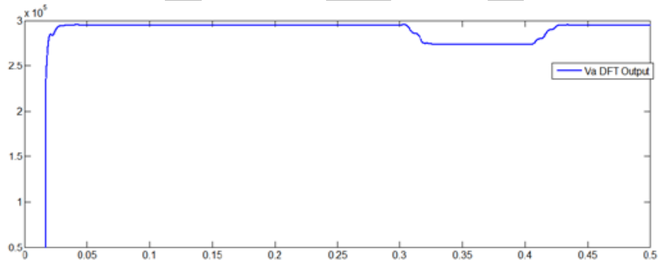


Figure 11.Voltage signals as appeared after DFT Model

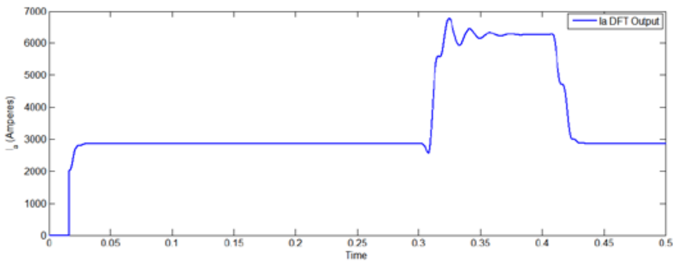


Figure 12.Current signals as appeared after DFT Model

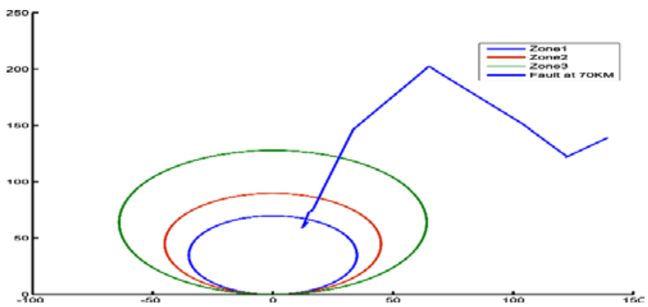


Figure 13.R-jX plot for a fault at 70 km distance

Paper ID: EE01

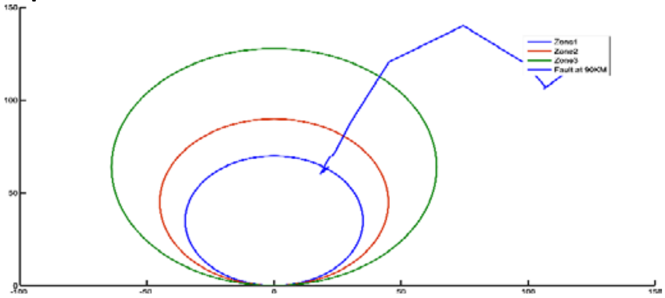


Figure 14. R-jX plot for a fault at 90 km distance

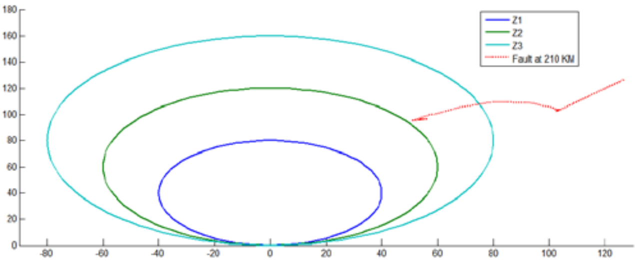


Figure 15.R-jX plot for a fault at 210 km distance

Three Phase to Ground Fault (ABCG Fault

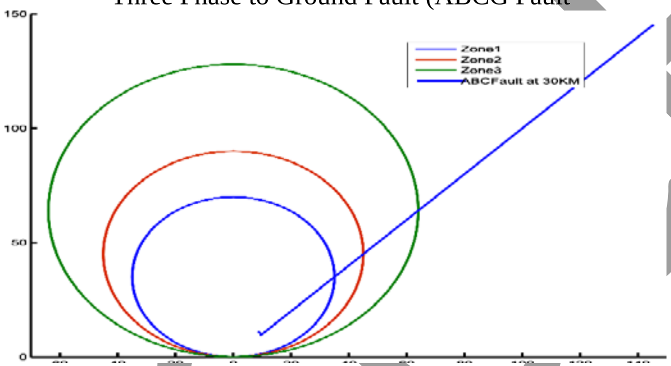


Figure 16.R-jX plot for a fault at 30 km distance

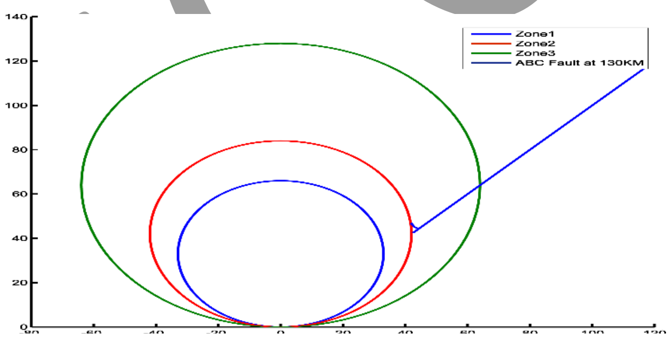


Figure 17.R-jX plot for a fault at 130 km distance

V. CONCLUSION

Using MATLAB/SIMULINK package aMHO type distance relay is developed. The performance of the developed relay is tested for different fault conditions. Using fault impedance algorithm relay is able to detect the correct type of fault. The developed relay also has ability to the fault in correct zone. Impedance plot correctly shows the operation of the relay under different fault conditions. It is possible to observe the performance of distance relay by changing simulation parameters like transmission line data, load data, power system data and fault data. The results of the performance characteristics of distance relay are shown for single line to ground fault and for three phase to ground fault at various locations on the transmission line. Thus use of relay model designing helps to expedite and economise the process of developing and testing new relays. For the future scope distance relay model can be developed for different characteristics and microcontroller can be used to improve its performance under different fault conditions.

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