Protection of Extra High Voltage Transmission Line Using Distance Protection

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Abstract: With growing complexity of modern power systems, faster, more accurate and reliable protection schemes have become essential. Typically, distance relays protect transmission line from power system faults by using the method of step distance protection. This method used the line impedance as the basis to form zones of protection and each zone is calculated by a predetermined percentage of the line impedance. In this paper, distance relay based protection scheme for 500kV transmission line in Myanmar is modeled and simulated by using MATLAB/SIMULINK package. The proposed model was verified under different tests, such as fault detection which includes single line to ground (SLG) fault, double line to ground (LLG) fault, Line to Line (LL) fault and three phase fault, all types of faults were applied at different locations to test this model. The results show that the relay operates correctly under different locations for each fault type. The difficulties in understanding distance relay can be cleared by using MATLAB/SIMULINK software.

Keyword: Power system protection, distance relay, line parameter, zone of protection, MATLAB/SIMULINK.

INTRODUCTION:

Distance protection is the most widely used to protect transmission lines. The fundamental principle of distance relaying is based on the local measurement of voltages and currents, where the relay responds to the impedance between the relay terminal and the fault location [1]. There are many types of distance relay characteristic such as mho, reactance, admittance, quadrilateral polarized-mho, offset mho etc. Every type of characteristics has different intended function and theories behind [2].

In order to understanding the function of relays, software relay models must be realized and feasible alternative to studying the performance of protective relays. Relay models have been long used in a variety of tasks, such as designing new relaying algorithms, optimizing relay settings. Electric power utilities use compute-based relay models to confirm how the relay would perform during systems disturbances and normal operating conditions and to make the necessary corrective adjustment on the relay settings. [3][4]. One of the world-wide recognized, powerful analysis software package, is a MATLAB/SIMULINK, which has the capability for modeling, simulating and analyzing dynamic systems using SimPowerSystems toolbox, in side Simulink package, different parts of a system such as three phase transformer, three phase load, distributed parameters line, circuit breaker, etc can be used for AC and DC applications. [5].

The aim of this paper is to explain the building process of Simulink model for distance relay, inside the modeling, fault detection, apparent impedance calculation for all types of faults, zone coordination were designed and implemented, a Mho type distance characteristic was chosen to be as the protection scheme for this relay is the developed model can be included in one block set only by creating the subsystem for the developed model. The created subsystem block set also can be copied and pasted at any space or file thus eliminates the multiple building of the model. Recently, 500kV transmission lines are being installed in Myanmar, the protection system and it was important to consider the reliable protection system for such Extra High Voltage transmission line.

MATERIALS: The demands imposed on protective relaying of transmission lines have continuously increased. To meet these demands new protective systems have been developed. In the transmission line protection, the use of distance relays has found to be the most feasible and effective as compared to the other type of protection such as current actuated relay (overcurrent relay). The overcurrent relays are principally dependents on only one actuating quality which is current. There are some parameters in transmission line like line resistance, source impedance, types of faults, fault location etc which affects the current measured by relay.

METHOD: MATLAB/SIMULINK provides a well-known too for modeling digital protective relays. SIMULINK offers a wide selection of libraries that allow detailed simulation digital relays. Aspects of digital relaying, such as signal conditioning, analog-to-digital conversion, digital filtering, phasor estimation, protection algorithms, and relay trip logic, can be modeled using general purpose blocks, special blocks from the signal processing block set and user defined blocks written in S-functions.[6].

***Discussion:** A. Basic Principle of Distance Relay*

A distance relay 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 reactance per kilometer related to its design and construction so its total impedance will be a function of its length. A distance relay therefore looks at current and voltage and compares these two quantities on the basic of Ohm's law. Since the impedance of a transmission line is proportional to its length, for distance measurement it is appropriate to use a relay capable of measuring the impedance of a line up to a predetermined point (the reach point). Distance relay is designed to operate only for faults occurring between the relay location and the predetermined (reach) point, thus giving discrimination for faults that may occur in different line sections. The basic principle of distance protection involves the division of voltage at the relaying point by the measured current. The calculated apparent impedance is compared with the reach point impedance. If the measured impedance is less than the reach point impedance, it is assumed that a fault exists on the line between the relay and the reach point.

B. Zones of Distance Protection

Distance relays use voltages and currents acquired at the relay location to calculate the apparent impedance of the protected line [4]. The calculated apparent impedance is compared with predetermined impedance that is called reach of the relay. During normal operation, the apparent impedance must be larger than the reach of the relay. If the apparent impedance is less than the impedance-reach, then a fault has occurred; as such, the relay energizes the circuit to trip the appropriate circuit breakers in order to isolate faulted line from the rest of the system [4]. Distance relays can have different characteristics including MHO, quadrilateral and reactance characteristics. The MHO type characteristic is optimal for phase-fault relaying for long transmission lines, and mainly where severe synchronizing- power surges may occur [5]. The typical practice in applying the R-X plane of MHO characteristic relaying is to install multiple sets of impedance relays at each relaying point, creating corresponding multiple zones as shown in Fig (2). The operating zones are defined such that whenever the ratio of V/I falls inside a circle, the relay unit operates R and X represent the resistive and reactive parts of the monitored impedance and can be in per-unit or ohms [6].

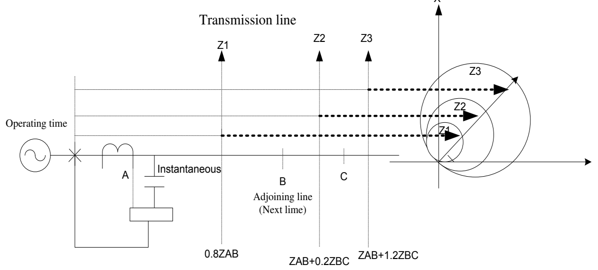

Fig.1. (a) Distance relay protection zones (b) MHO characteristics for three zones of protection

- Zone 1: this is set to protect between 80% of the line Length AB and operates without any time delay. This "under-reach" setting has been purposely chosen to avoid "over-reaching" into the next line section to ensure selectivity since errors and transients can be present in the voltage and current transformers. Also manufacturing tolerances limit the measurement accuracy of the relays.

- Zone 2: this is set to protect 100% of the line length AB, plus at least 20% of the shortest adjacent line BC and operates with time delay. It not only covers the remaining 20% of the line, but also provides backup for the next line section.
- Zone 3: this is set to protect 100% of the two liens AB, BC, plus about 25% of the third line CD and operates with time delay.

FAULT ANALYSIS:

A fault in a circuit is any failure that interferes with the normal flow of current to the load. Faults on transmission and distribution lines are caused by overvoltage such as lightning and switching surges and external conducting objects falling on overhead line. In most faults, a current path forms between two or more phase, or between one or more phases and the neural (ground). While the impedance of a new path is usually low, an excessive current may flow. Almost 70% of all faults are single line to ground faults. Nowadays, the fault analysis is become very important because it will be apply to reduce the fault occur at transmission line and generally in power system. There are two types of fault that occur on transmission lines such as balanced or symmetrical faults and unbalanced or unsymmetrical faults [7].

A. Types of Faults

The common type of faults occurrence at the transmission lines are:

- Balanced or symmetrical three-phase faults
- Single line-to-ground faults
- Line-to-ground faults
- Double line-to-ground faults

MHO RELAY ALGORITHM

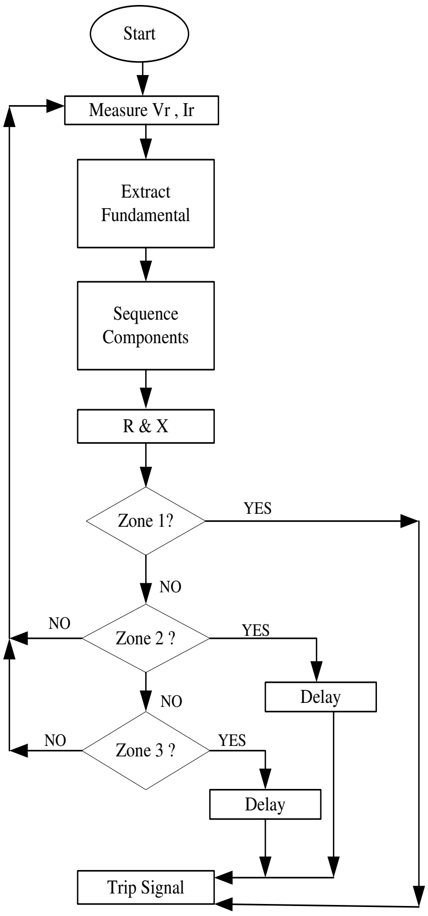

Figure.2.Mho Relay Modelling Algorithm [8]

Findings:

POWER SYSTEM DATA AND RELAY SETTING

TABLE I TRANSMISSION LINE DATA

Meikhtila-Taungoo Line Parameters		
No	**Parameters**	**Values**
1	Line Length	235.6km
2	Voltage(U)	500kV
3	Nominal frequency	50Hz
4	Line Resistance(R1=R2)	0.02642 Ω/km
5	Line Resistance (R0)	0.4296 Ω/km
6	Line Inductance (L1=l2)	0.7376e-3 H/km
7	Line Inductance (L0)	5.5024e-3 H/km
8	Line Capacitance (C1=C2)	28.8579e-9 H/km
9	Line Capacitance (C0)	14.4289e-9 H/km
10	Total zero sequence impedance	$184.638\angle 76.042^0\Omega$
11	Total Positive sequence impedance	$24.1758\angle 83.495^0\Omega$

TABLE II. TRANSMISSION LINE DATA

Taungoo-Hpayargyi Line Parameters		
No	**Parameters**	**Values**
1	Line Length	188.4 km
2	Voltage(U)	500kV
3	Nominal frequency	50Hz
4	Line Resistance(R1=R2)	0.02642 Ω/km
5	Line Resistance (R0)	0.4296 Ω/km
6	Line Inductance (L1=l2)	0.7376e-3 H/km
7	Line Inductance (L0)	5.5024e-3 H/km
8	Line Capacitance (C1=C2)	28.8579e-9 H/km
9	Line Capacitance (C0)	14.4289e-9 H/km
10	Total zero sequence impedance	$335.564\angle 76.04^0\Omega$
11	Total Positive sequence impedance	$43.9196\angle 83.495^0\Omega$

TABLE III. SETTINGS OF ZONES OF PROTECTION

Zone	Setting	Values R(Ω)	Values X(Ω)

Zone 1	80% T.L-1	2.191Ω	19.216Ω
Zone 2	T.L-1+20% T.L-2	3.177Ω	27.86Ω
Zone 3	120%[T.L1+20%T.L2]	3.8124Ω	33.432Ω

SIMULINK MODEL FOR EHV LINE UNDER STUDY

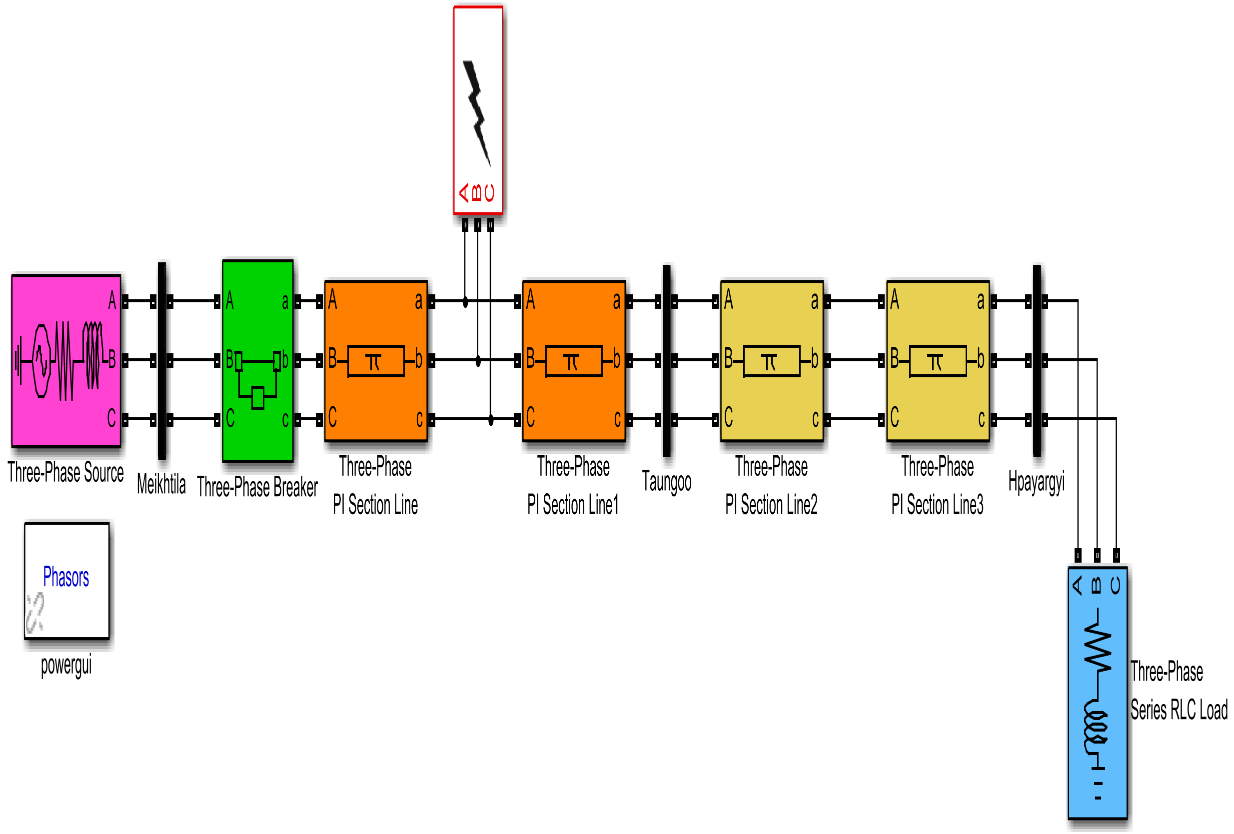

Figure.3. Simulation Model for EHV Transmission Line

Firstly, the simulation model for 500kV Extra High Voltage Transmission line in Myanamr, Meikhtila-Taungoo-and , Hpayargyi, line parameters were calculated, as shown in Table I, II, and several operating and fault conditions have been simulated in order to validate the relay model and the settings of the relay model used are in Table. .where,R= resistance, L=inductance, C= capacitance.

BUILDING DISTANCE RELAY MODEL AND SIMULATION RESULTS

In the following, the main functions included in the digital relay model are presented.

1- Fault detection block
2- Impedance measurement
3- Zone Selection

In the fig.5 shows the fault detection block built in MATLAB, it is clear the relay can discriminate all types of fault. The relay permit direct detection of phases involved in a fault or called fault phase selection, which permits the appropriate distance-measuring zone to trip. Without phase selection, the relay risks having over or under reach problems, or tripping three phases when single-pole fault clearance is required.

A. Fault Detection Block

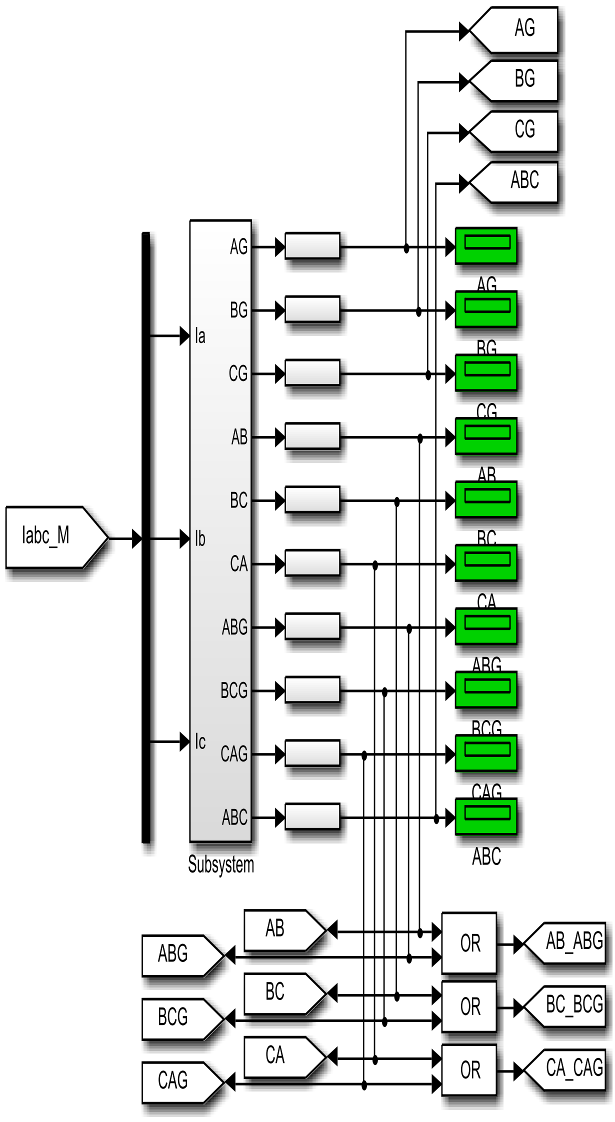

Figure.4. Fault Detection Block

Results:

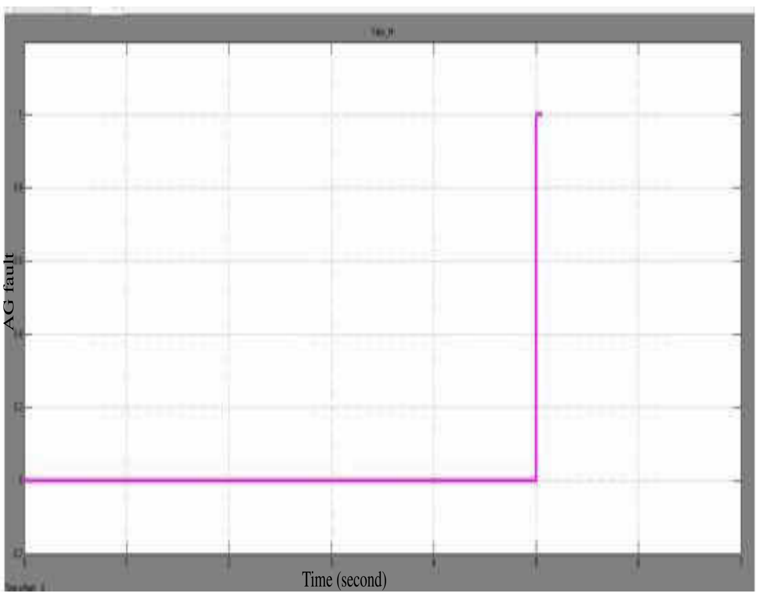

Figure.5. Simulation results for Single-line-to ground fault

Simulation results of single-line-to ground fault as shown in fig.5. According to the simulation results, fault detection block can be seen in display.

B. Impedance Measurement

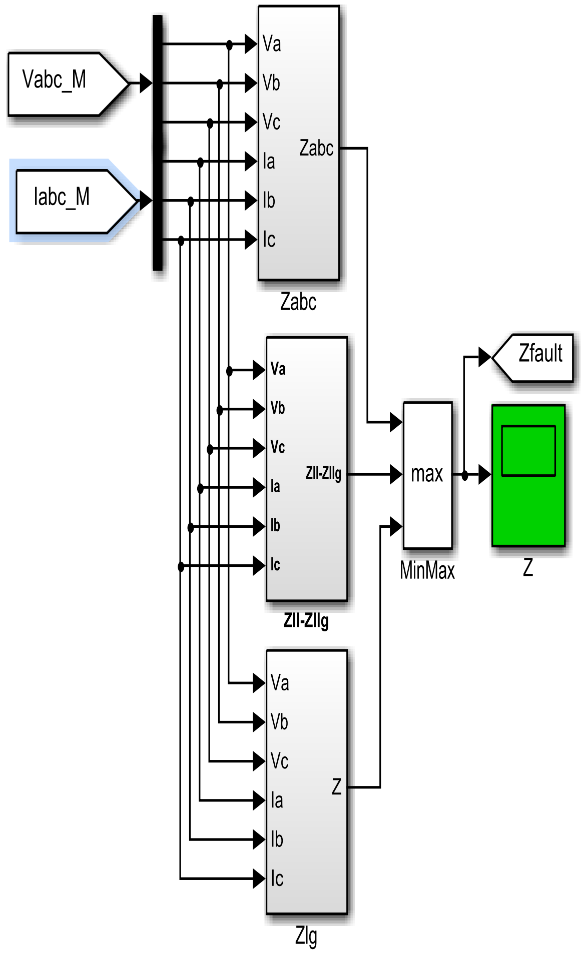

Figure.6.. Impedance Measurement Block

The fault detection block, determined the fault type, and then sends a signal to the impedance measurement block and it consists of different subsystems used to compute the fault impedance for different types of fault.

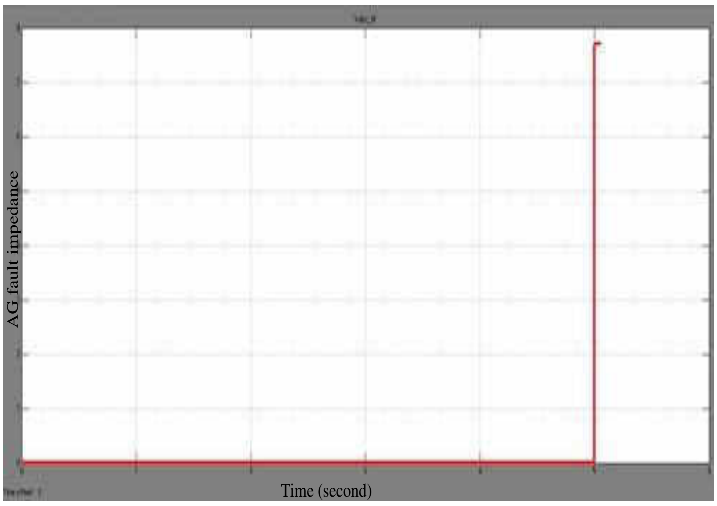

Figure.7. Simulation results for Single-line-to ground fault impedance

Simulation results of single-line-to ground fault impedance as shown in fig.7. According to the simulation results, in impedance measurement can be seen in display.

C. Zone Selection

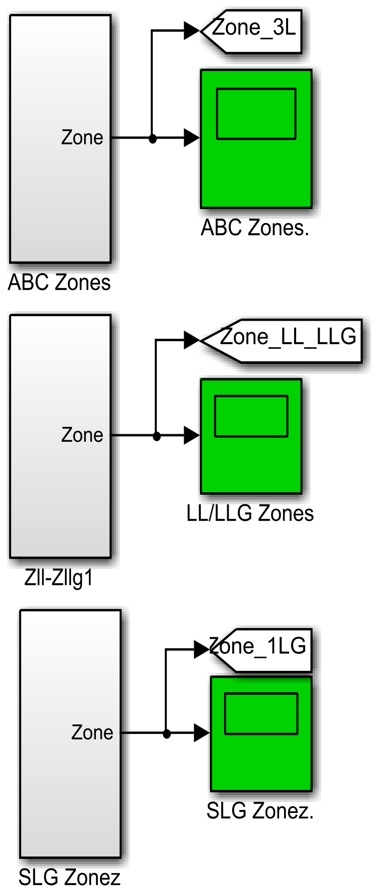

Figure.8. Zone Selection block

Figure shows, which determines Single-Line-to-Ground fault zone, Double line to ground fault zone and three phase fault zone.

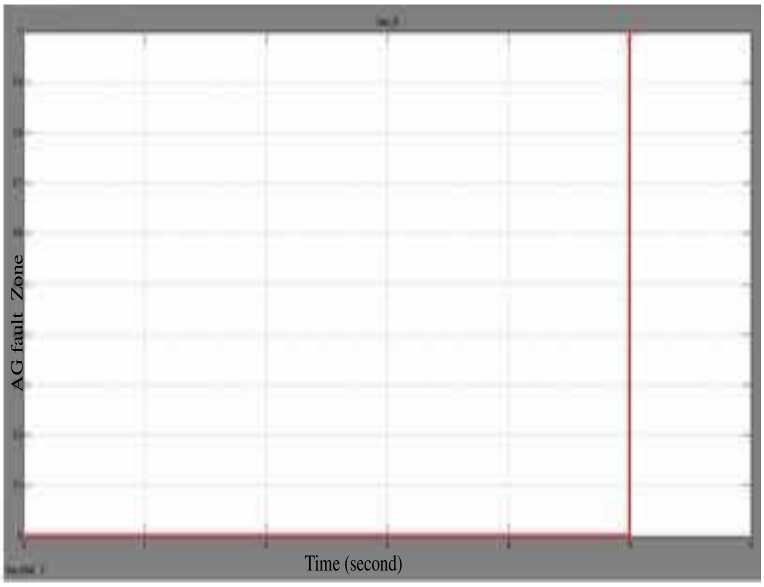

Figure.9. Simulation results for Single-line-to ground fault zone

Simulation results of single-line-to ground fault zone as shown in fig.9. According to the simulation results, in fault zone measurement can be seen in display.

RECOMMENDATIONS:

For development and evaluation of fast and accurate fault diagnostic scheme, i.e., fault detection, classification and isolation of transmission line systems, AI based digital relaying system will be proposed. For design and implementation of microprocessor and AI based protection systems with the various relaying scheme. For improvement in reliability and accuracy of protection system used in Extra High Voltage Transmission Line will be described.

CONCLUSION:

A Mho type distance relay was successfully developed based on MATLAB/SIMULINK package, (each part of the relay is implemented as a separate function). Each function has been created using special blocks of SIMULINK. By testing the behavior of the developed relay model under different fault conditions, the relay model was able to recognize the appropriate fault type. From perspective impedance calculations, the relay model has the ability of indicating the correct zone of operation in all cases. The relay identifiers the fault locations as expected, as the fault location is changed, the measured impedance change consequently. The impedance path which reflects the behavior of the model under different fault conditions was presented and discussed.

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