International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 09 || September 2017 || PP. 102-108

Designing and Implementation of Numerical Distance Relay

Kuldeep Pippal[1], Kiran Pathekar[2], Akash Shrivastava[3], Jeevan Matele[4]

[1]*M.Tech scholar, Kopal Institute of Science and Technology, Bhopal, India*
[2]*M.Tech scholar, Kopal Institute of Science and Technology, Bhopal, India*
[3]*M.Tech scholar, Kopal Institute of Science and Technology, Bhopal, India*
[4]*M.Tech scholar, Kopal Institute of Science and Technology, Bhopal, India*

Abstract: This paper presents the design and modeling of numerical distance relay for transmission line faults. The relay was built and simulated using SIMULINK environment of MATLAB software. The phase to ground fault was chosen as the fault type and Mho relay is taken for the protection.

Index Terms: Numerical distance relay, fault, DFT, simulation

I. INTRODUCTION

Electric power system has undergone numerous changes and is getting more complex due to the integration of power grids. Electric power systems consist of the equipments that generate, transmit and distribute electrical energy. Since bulk amount of power with continuity of supply is required, the system must be capable to supply the power without interruption. Most of the interruptions or faults occur in transmission lines (50% of total) and hence a strong protection scheme is the main requirement of any system.

Majority of the faults are transient in nature. There are 4 types of faults viz. single line to ground fault, double line to ground, line to line, and three phase to ground fault. A fault may be single or the combination of the above. So the fault must be detected and cleared as soon as possible. It is very important to have a suitable relay type or relay's setting in any protection scheme to clear these faults.

Numerical distance relays, owing to their high speed of fault clearance compared with the over current relays is a widely used protection scheme for the protection of High Voltage (HV) and Extra High Voltage (EHV) transmission and sub-transmission lines. A numerical relay finds the actual electrical distance of fault & compares the result obtained with a pre-given threshold, which determines the protection zone. Numerical distance relays provide an excellent way of obtaining zone discrimination, selectivity and speed of operation by ensuring precision trip decision up to a certain range of distance [1] and [2]. Distance relays are actually evolved from the conventional electromechanical relays to static relays & to microprocessor based (digital) relays. Numerical distance relays employs microprocessors which are especially designed to process the digital signals, which makes them quicker & more powerful.

In general, transmission line protection is provided by distance protection. Its mode of operation is based on the measurement of the voltage and current, these parameters are further used for the calculation of impedance of the circuit. Impedance is proportional to the distance of the fault. A distance relay measures the impedance between the relay location and the point of fault. When a fault occurs in the protected zone of a relay, the voltage at the relay is equal to the product of current and impedance of the line, i.e. IZ. So, the voltage to current ratio measured by the relay equals the line impedance Z [3]. Since V/I is proportional to the distance of the line between the relay and the fault, so V/I is actually the impedance of the fault [4]. A distance operates for faults that occur only between its location and the selected point. The line to be protected is divided into various zones or regions. In general practice, the first zone is set normally between 85% to 90% of the line to be protected, If the zone or reach of the distance relay is set to 100% then over-reach will cause loss of selectivity with the distance protection of the next section, therefore it is a general practice to use 85% to 90% of the section of line to be protected. The second zone is generally between 120% to 150% of the line to be protected and the third and the last zone of protection generally extends to 150% of the next line section or zone [5].

II. PRINCIPLE OF OPERATION

The principle of operation of a distance relay is shown in the figure 1, it involves voltage division at the relaying point by the measured current i.e. the ratio V/I. The apparent impedance of the relay is compared with the reach point impedance. If observed impedance is less than reach point impedance, then it is assumed that a fault exists on the network, between the relay & our reach point. The relay is connected at position, R and receives a secondary current, equivalent to a primary fault current, "I_F". The secondary voltage "V_F" is equivalent to the product of the fault current "I_F" and impedance of the line up to the point of fault, Z_F. The operating torque of this relay is proportional to the fault current "I_F", and its restraining torque is proportional to the voltage "V_F".

Also there will be a definite ratio of V/I at which the torque will be equal. This is actually the reach point setting of the relay.

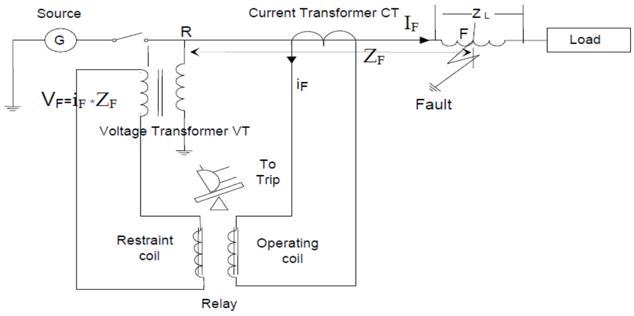

Fig. 1. Principle of operation of distance relay

The relay operates when the operating torque becomes greater than restraining torque. Thus any increase in current coil ampere-turns, without a corresponding increase in the voltage coil ampere-turns, will unbalance the relay. This means the V/I ratio has fallen below the reach point [6]. Alternatively if the restraining torque is greater than the operating torque, the relay will restrain and its contacts will remain open. In this case the V/I ratio is above the reach point. The reach of a relay is the distance from the relaying point to the point of fault. Voltage on the primary of voltage transformer, VT, is:

$$V = \frac{EZ_f}{Z_s + Z_f}$$

And fault current I_F

$$I_f = \frac{E}{Z_s + Z_f}$$

The relay compares the secondary values of V and I, as to measure their ratio which is an impedance Zm.

$$Z_m = \frac{V}{\text{PT Ratio}} \Big/ \frac{I}{\text{CT Ratio}}$$

Therefore,

$$Z_m = Z_f * {}^{\text{CT Ratio}}/_{\text{PT Ratio}}$$

Zm is the measured impedance called secondary impedance.

III. NUMERICAL RELAY STRUCTURE

The structure of the typical digital relay is shown:

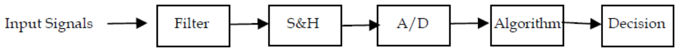

Figure.2 Numerical relay structure

Where, S&H- Sample and Hold, A/D- Analog to Digital converter.

These are modules which constitute the general numerical distance relay, and different relaying function is obtained from the same hardware by modifying the programming of microprocessor.

IV. MODELLING AND SIMULATION

Whenever a transmission line fault occurs, the voltage and current signals gets distorted. They may contain certain harmonics, subsystem frequency transients, dc components (offsets), high frequency oscillations etc. Harmonics and frequency transients are removed easily by a filter (mimic filter) with a suitable cut-off frequency but DC offset components are difficult to remove. This makes us difficult to measure and calculate the voltage and current phasors. The Discrete fourier Transform (DFT) is a widely used technique to calculate fundamentals phasors of voltage and current signals.

The voltage and current measured is passed through a low pass filter before sampling, then DC- offsets are corrected thus we calculate Impedance Z, by using DFT algorithm.

A. DC offset removal using mimic filters

In general, the mimic filter is used to remove the dc-offset components.

The mimic filter can be developed by digital method. Here, we want to pass the fundamental frequency signal (50Hz) by the filter. Then, assuming the gain K equals 1 and the sample frequency is fs (fs = 1/Ts), finally, we obtain a formula as

$$|K(1+\tau f_s) - K\tau f_s \cos(\omega T_s) + jK\tau f_s \sin(\omega T_s)| = 1$$

Where ω = 2π*50, and τ is time constant for user definition.
By solving the above equation, we can get the gain K.

$$K = \text{sqrt}\left(\frac{1}{M^2 + N^2}\right)$$

Where,

$$M = 1 + \tau f_s - \tau f_s \cos\frac{2\pi * 50}{f_s}$$

$$N = \tau f_s * \sin\frac{2\pi * 50}{f_s}$$

MATLAB can easily calculate the algorithms for the protective relays. With the advantage that SIMULINK can easily simulate power system faults, the design & the test of protective relays can be achieved with ease. The property of being able to integrate the system fault simulation and protective relaying algorithms in a software system enhances the efficiency of the protection relay test.

B. Algorithm for DFT

Since both the current and voltage signals are periodic in nature, it is quite easy to calculate the impedance (Z) corresponding to the measured values of current and voltage by determining the fundamental component of voltage and current using Discrete Fourier Transform (DFT).
Let number of samples be N for each period and X(K) be the discrete time signals. Then the the full cycle DFT sampled signal is given by-

$$X = \frac{2}{N}\sum_{k=0}^{N-1} x_k e^{-j2\pi k/N}$$

Where, n = number of cycles, The fundamental frequency can be calculated by taking n=1.

The fundamental component of voltage and current signals, impedance i.e. resistance and reactance are calculated as follows:

$$R_K = \frac{V_K}{I_K + 3.\text{Re}(K_0).I_{0K}} \qquad X_K = \frac{V_K}{I_K + 3.\text{Im}(K_0).I_{0K}}$$

Where,

K_0 = compensation factor
I_0, = zero sequence current
V_k, I_k = sampled voltage and current respectively

Given below is the algorithm for impedance calculation.

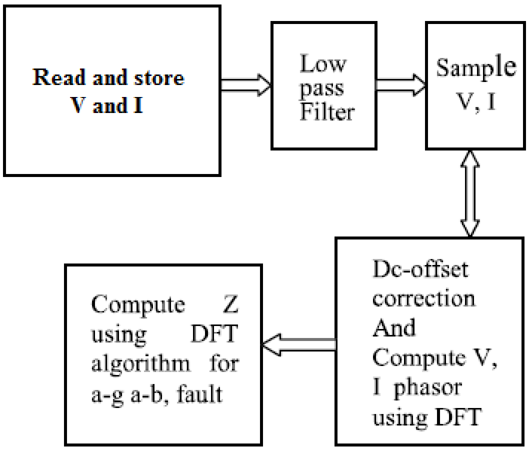

Figure.3. Impedance calculation algorithm

V. RELAY SIMULATION

SIMULINK is used for this purpose, it is an interactive tool for modeling, simulating and analyzing dynamic systems, including control and many complex systems. To get the exact simulation results, we should establish an accurate network model. So SIMULINK/Power System Block set (PSB) is used to create power system model for simulation.

It is very easy to create power system in SIMULINK environment, which allows users to create a model by simple “click and drag” procedures. It is also very easy to include its interactions with every electrical component. [7]

Flow chart diagram for the simulation process is given below.

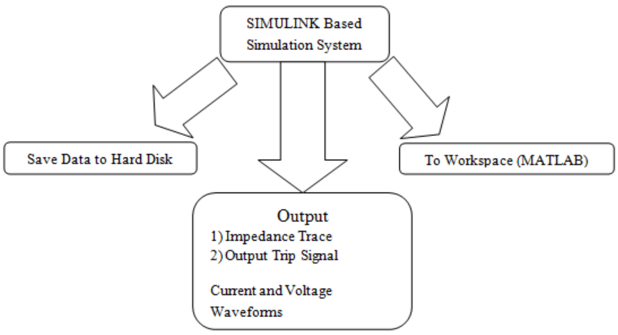

Fig. 4. Flow chart diagram for the simulation process.

Fig.5 shows the block diagram for the developed distance relay.

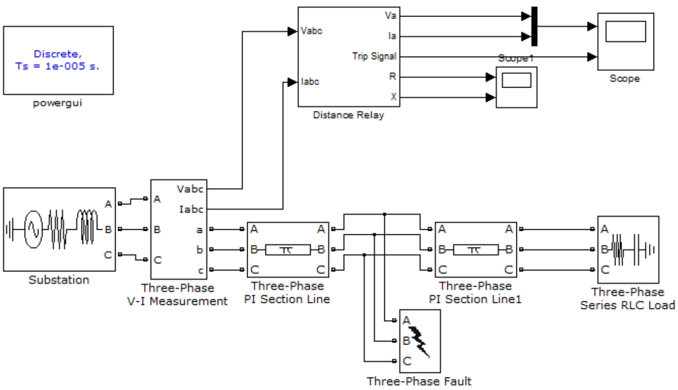

Fig. 5. Block diagram of Numerical distance Relay.

The parameters used for simulation for protection of a transmission line using numerical distance relay:

Line Voltage: 132 KV

System Frequency: 50 Hz

Line Length: 86km

Line Constants:

R_o= 0.1239 Ω/km, L_o= 1.30157 mH/km, C_o= 10^{-9} F/km

R_1= 0.01239 Ω/km, L_1= 0.43386 mH/km, C_1= 10^{-9} F/km

An S-LG fault is simulated on phase A, from T = 0.1 Sec. to T = 0.4 Sec. with a fault resistance of 0.01Ω and ground resistance of 0.01Ω.

Since the type of fault selected for the simulation was Single Line to Ground (S-LG) fault, the block parameters taken are:

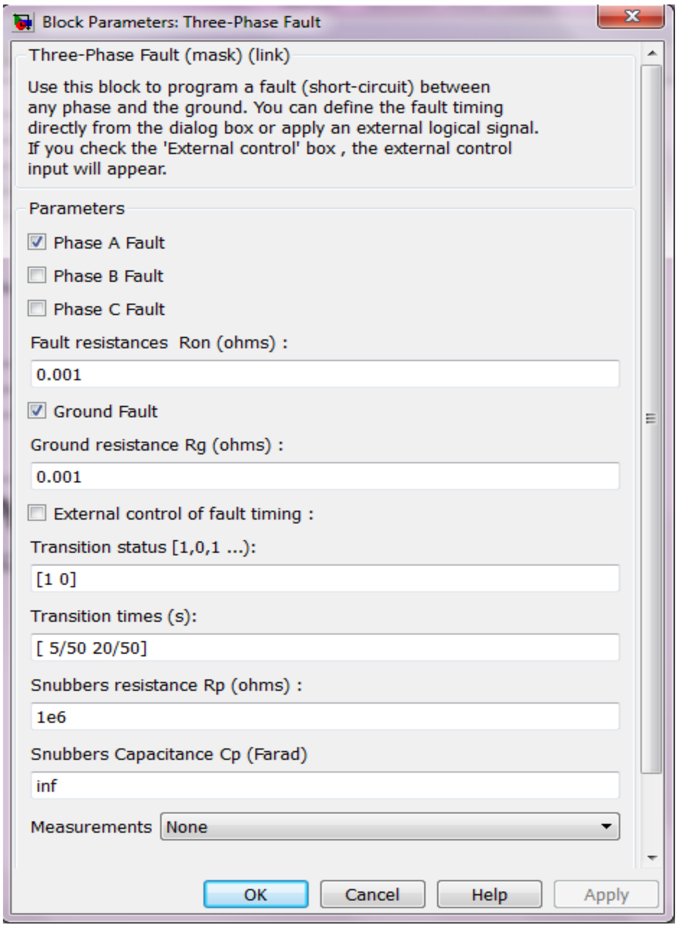

Fig. 6. SLG fault simulation

VI. SIMULATION RESULTS

Output of the numerical distance relay for a fault on the system is given in fig 8. Change in the measured impedance is shown below in fig. 7, which shows how Z= R+jX get changed during the fault.

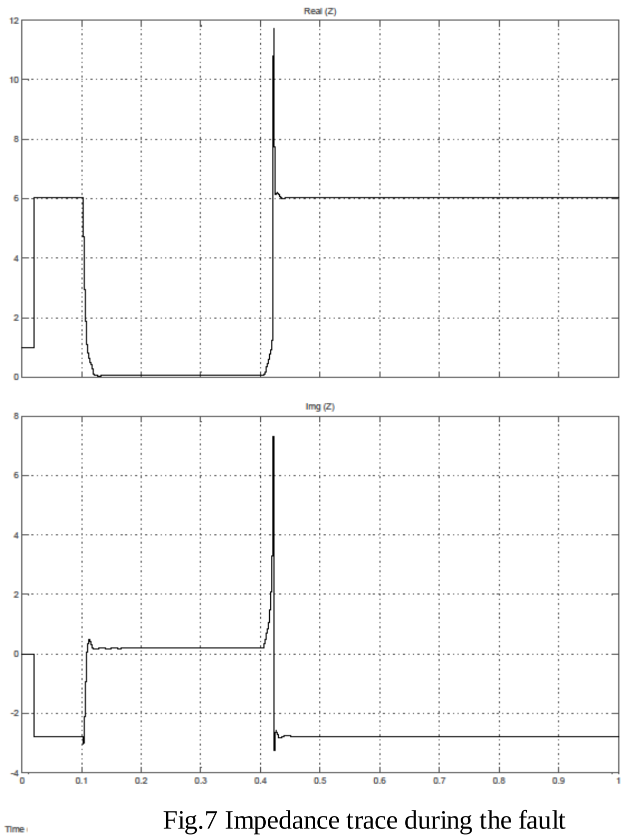

Fig.7 Impedance trace during the fault

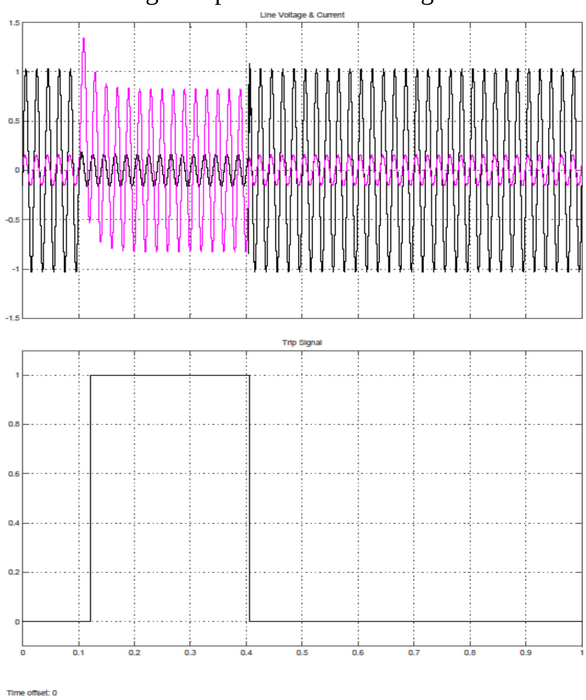

Fig. 8. Voltage and Current variation and Trip signal

VII. CONCLUSION

This paper represents the numerical distance relay model based on MATLAB/SIMULINK. SIMULINK as we know has powerful capabilities for Graphical Interface. The relay working can be easily understood by the model. It can help protection engineer to enhance the performance of the digital relay design selection and erection process. The results obtained were excellent and easily understood.

VIII. ACKNOWLEDGMENT

The authors would like to express their thanks and gratitude to the Department of Electrical and Electronics, Kopal Institute of Science and Technology, Bhopal for their help, support and guidance in the work.

IX. REFERENCES

[1]. Badri, Vishwakarma, Ram. D, "Power System Protection and Switchgear", Tata McGraw Hill, 2007.
[2]. Implementation of DSP Based Numerical Three-Step Distance Protection Scheme for Transmission Lines.
[3]. Cook, V. 1985, "Analysis of Distance Protection" Research Studies Press Ltd., England. 204 p.
[4]. Dechphung, S. and T. Saengsuwan. 2008, "Three Zones Adaptive Characteristic of the Mho Distance Relay by KU Method" pp. 1352-1356 ICSET 2008 IEEE International Conference, Singapore.
[5]. Ziegler, G. 1999, "Numerical Distance Protection Principle and Application" Siemens AG.,Berlin and Munich, July, 341 p.
[6]. Abdlmnam A. Abdlrahem, H.H. Sherwali, "Modelling of numerical distance relays using MATLAB" ISIEA 2009, IEEE conference ,Kuala Lumpur.
[7]. Li-Cheng Wu, Chih-Wen Liu, Ching-Shan Chen, "Modeling ang testing of a Digital Distance Relay sing Matlab/SIMULINK", 2005 IEEE.