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Development of an Algorithm for Impedance Relay Transmission Line Protection

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ABSTRACT: *Power Systems are constructed with utmost care so that faults do not emanate due to errors in design. Faults however are inevitable, as they may occur due to bad weather, natural disaster and so on. In the situation of fault, one fault often triggers the shutdown of all. To mitigate the effect of faults on transmission line and to isolate faults without total system shutdown, this research came up with a design model. In this model, the transmission line is designed with the application of the impedance relay operational characteristics in modeling and simulation using in the Matlab/Simulink environment, simulation is carried out, and the analog signal is extracted, filtered, discretized and fed into the Discrete Fourier Transform Component where the magnitude of the voltage and current phasors are determined. The tests and comparisons are conducted and the results are discussed and analysed.*

KEYWORD: Matlab/Simulink, Discrete Fourier Transform, Power Systems,Impedance Relay,

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I. INTRODUCTION

To maintain normal power system operation without any electrical failure or equipment damage two steps should be considered by the engineer. One, to design the power system such that, fault can never occur in it. The other is to design the system such that even if fault occurs in it, it will use its guarding effects and control the effect of the fault to avoid the damage of equipment [1]. Gupter

Faults in power system are referred to as inevitable abnormalities which occur disrupting the normal power flow in the system.

Fault can be prevented to a large extent, if the system is carefully designed with good insulation coordination and maintenance.

These faults can be grouped into balanced and unbalanced faults. While the balanced faults are the fault that occur in the power system when the system still stable, but shows different abnormal output component results different from the standard accepted ones. Example of this fault is three phase short circuit (ABCG or L – L - L) and frequency faults. These faults can be so severe and difficult to be cleared since the system is running. Unbalanced faults are the faults that occur in the system when the system is unbalanced. These types of fault occur often and are not severe as previous. Examples of these faults include; single line to ground (AG, BG and CG), double line to ground (ABG, BCG, and ACG) and line to line (AB, BC and AC) faults.

A. PROTECTION SCHEME

To protect the power system, a protection scheme is designed which consist of many devices that help together to achieve the protection of the system. Each type of fault on the power system has its own protection scheme [1].

Every protection scheme comprises of the following; a pair of station battery, instrument (current and voltage) transformers, relay, circuit breakers, fuses, surge protectors etc.

B. PROTECTIVE RELAYS

This is an electrical protective device designed to initiate isolation of certain location on an electrical circuit in the event of an abnormal condition such any of the class fault above. This circuit could be AC or DC in which power system transmission line is an example of the AC circuit.

Generally, all relays employ for protection against effects of electrical faults operate by considering the variation in magnitude of current or voltage supplied to the current or voltage transformer on the scheme. This is because, faults occurrence is the result of the proportionate change in magnitude of current and voltage supplied to the protective relay.

At every points and types of fault, there is always a clear difference in the parameters of the power system. Each of the relays is designed to recognize a particular difference (abnormality) and operate in response to it. These differences may be in terms of magnitude, frequency, phase angle, rate of change, harmonics (wave shape), and period of occurrence of fault [1] [2].

The relay operation can also be classified as either electro – magnetic attraction or electro – magnetic induction. But in this paper we are considering only the application of the impedance relay operational characteristics in modeling and simulation using MATLAB/SIMULINK.

II. METHODOLOGY

First: develop the power system transmission line of 150km, 132kV, three generators, 150MVA transformer, 90MVA load connected to it.

Secondly: simulate the developed model and extract the waveform signal for both at pre-fault and fault conditions.

Thirdly: filter the analog signals to eliminate the possible harmonics contents which may be present due to arcing of fault.

Fourthly: convert the analog wave signals to digital (discretize) by using discretization formula and certain sampling frequency.

Fifthly: apply or sample the digital signals into Discrete Fourier Transform (DFT) to calculate the discrete values of voltage and current phasor values.

The relay compares the relay settings of the impedance with the measured impedance on the line to determine if the fault is inside or outside the protected zone. It then releases immediately a trip signal when the impedance value is inside the zone.

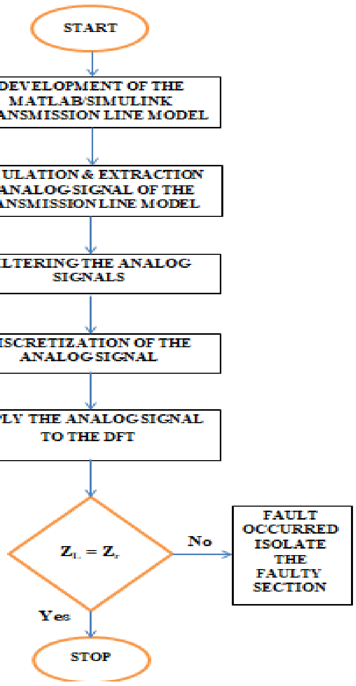

Figure 1: Flowchart of the Impedance Relay modeling and its implementation

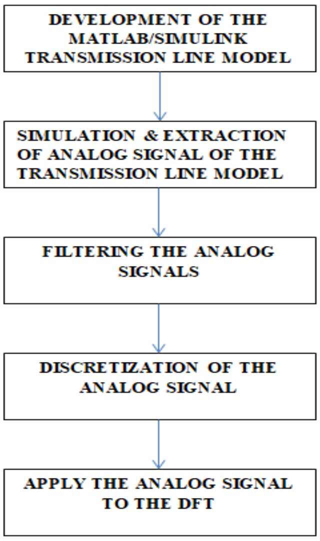

Figure 2: Block Diagram of the Impedance Relay modeling

A. ALGORITHM FOR IMPEDANCE CALCULATION

The following formula were used for the impedance relay calculation and modeling with MATLAB/SIMULINK.

$$AB = \frac{V_a - V_b}{I_a - I_b}$$

$$BC = \frac{V_b - V_c}{I_b - I_c}$$

$$AC = \frac{V_a - V_c}{I_a - I_c}$$

$$AG = \frac{V_a}{I_a + [3k_0 I_0]}$$

$$BG = \frac{V_b}{I_b + [3k_0 I_0]}$$

$$CG = \frac{V_c}{I_c + [3k_0 I_0]}$$

$$ABCG = \frac{V_a}{I_a} = \frac{V_b}{I_b} = \frac{V_c}{I_c}$$

Where A, B and C are phases of the three lines, V_a, V_b, V_c are the lines A, B and C voltages while I_a, I_b, I_c are lines A, B and C currents.

Also,

$I_0 = \frac{I_a + I_b + I_c}{3}$ = zero sequence current respectively.

$k_0 = \frac{Z_1 + Z_0}{3Z_1} =$

Z_1 = Positive sequence impedance

Z_0 = Zero sequence impedance

B. DEVELOPMENT OF THE IMPEDANCE RELAYMODEL

MATLAB/SIMULINK blocks were used extensively in the development of the relay model.

The discrete 2nd order filter has been used for filtering the analog signal. The Discrete Fourier Transform (DFT) has also been used to determine the magnitude of voltage and current phasors.

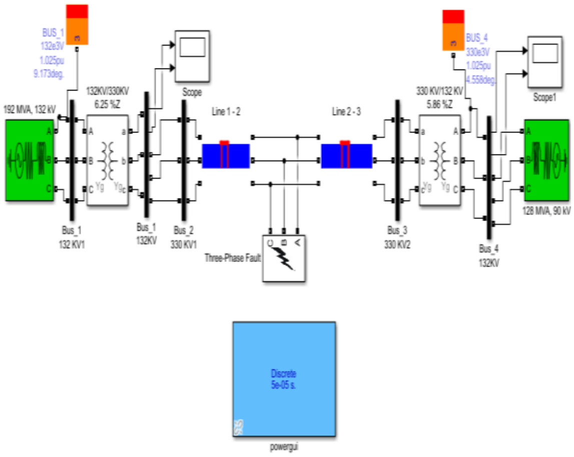

Figure 3: MATLAB/SIMULINK Model of the developed transmission line

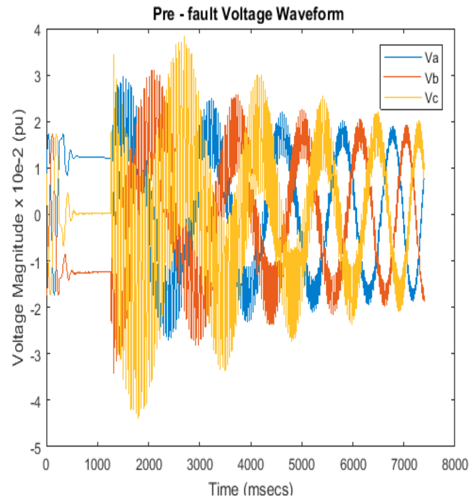

Figure 4: Pre-fault Voltage Signal Waveform

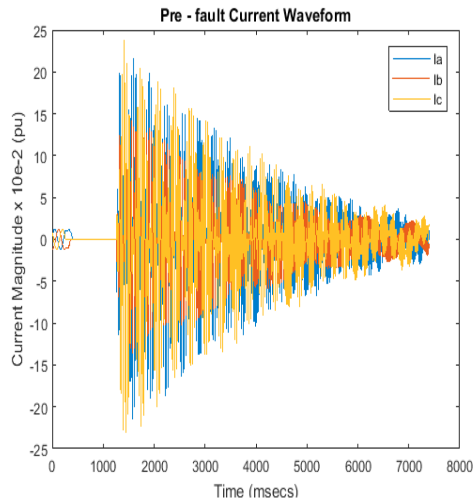

Figure 5: Pre-fault Current Signal Waveform

Figure4 & 5 show pre-fault voltage and current waveforms withvarying magnitudes which are due to harmonics on the lines coursed by nonlinear loads.

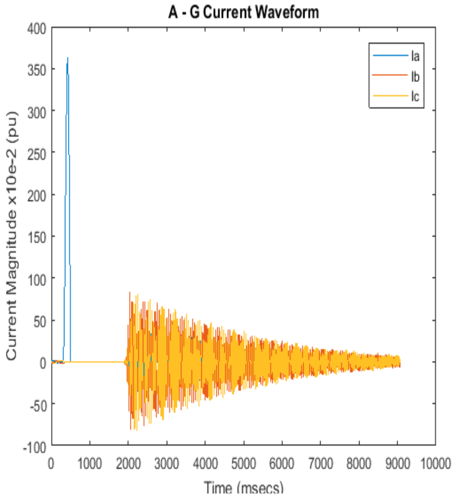

Figure 6: A – G fault Current Signal

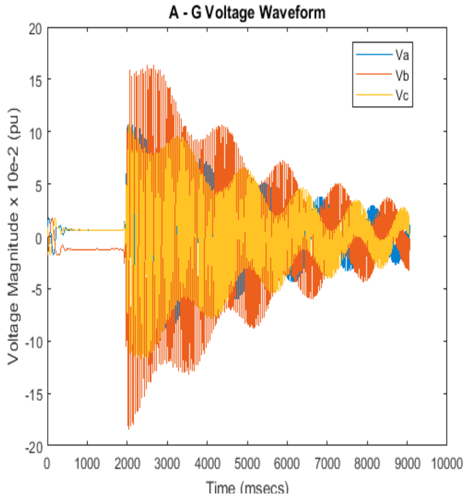

Figure 7: A – G fault Voltage Signal Waveform

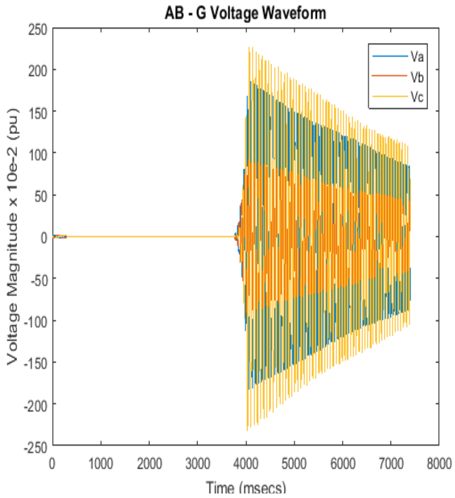

Figure 8: AB – G fault Voltage Signal Waveform

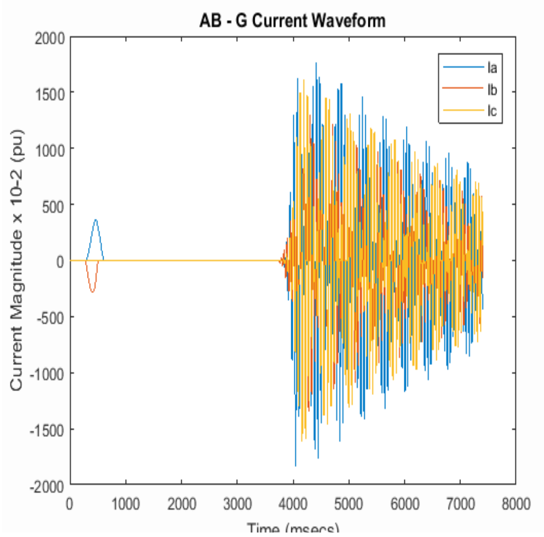

Figure 9: AB – G fault Current Signal Waveform

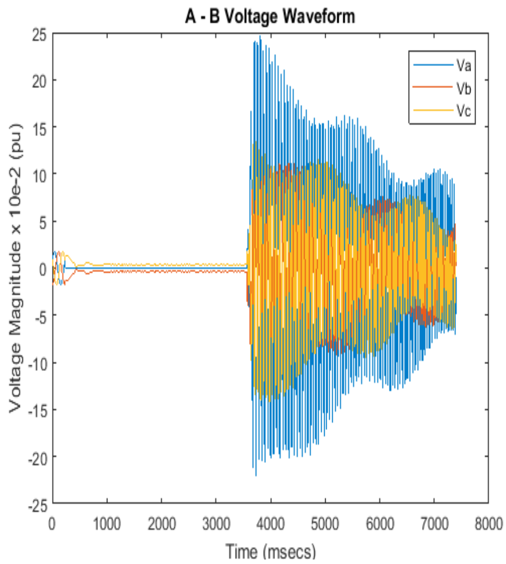

Figure 10: A – B fault Voltage Signal Waveform

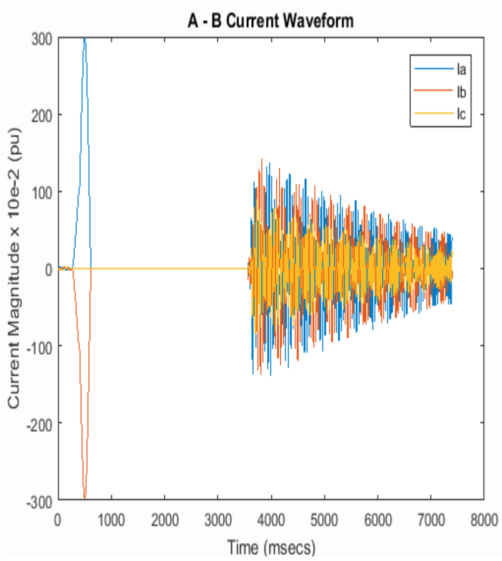

Figure 11: A – B fault Current Signal Waveform

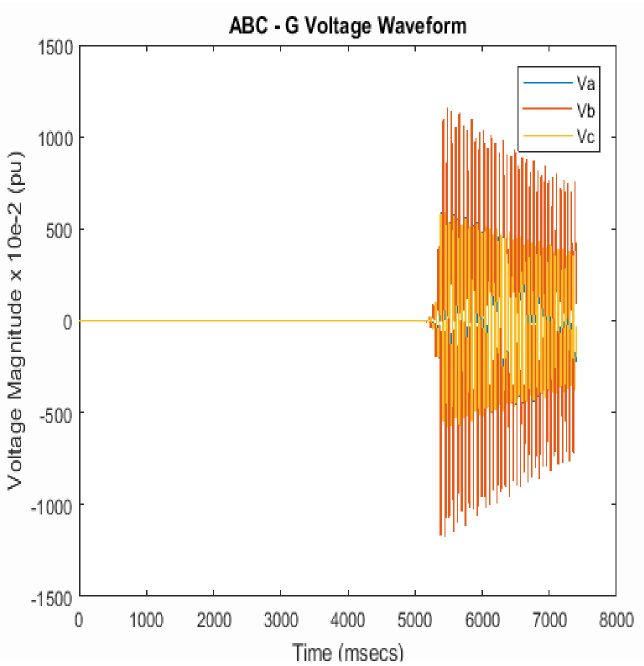

Figure 12: ABCG fault Voltage Signal Waveform

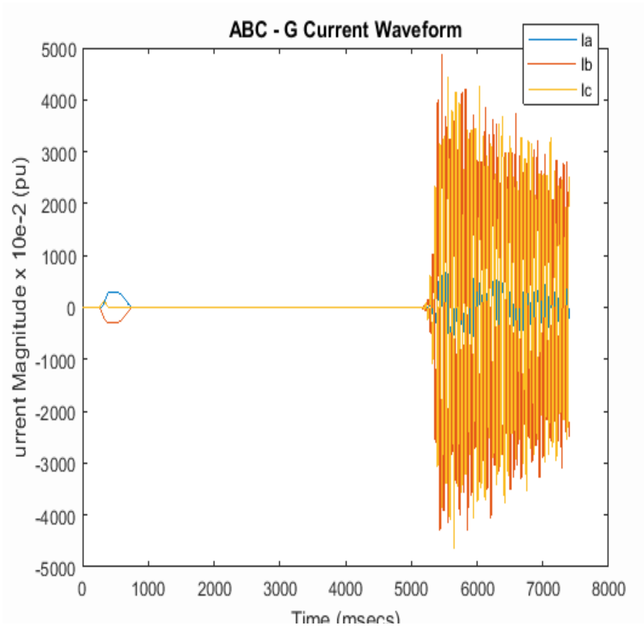

Figure 13: ABCG fault Current Signal Waveform

The increase in the magnitudes of current and voltage of figure 6 & 7, 8 & 9, 10 & 11 and 12 & 13 were as result of the presence of the A – G, AB – G, A – B and ABC - G faults on the line respectively.

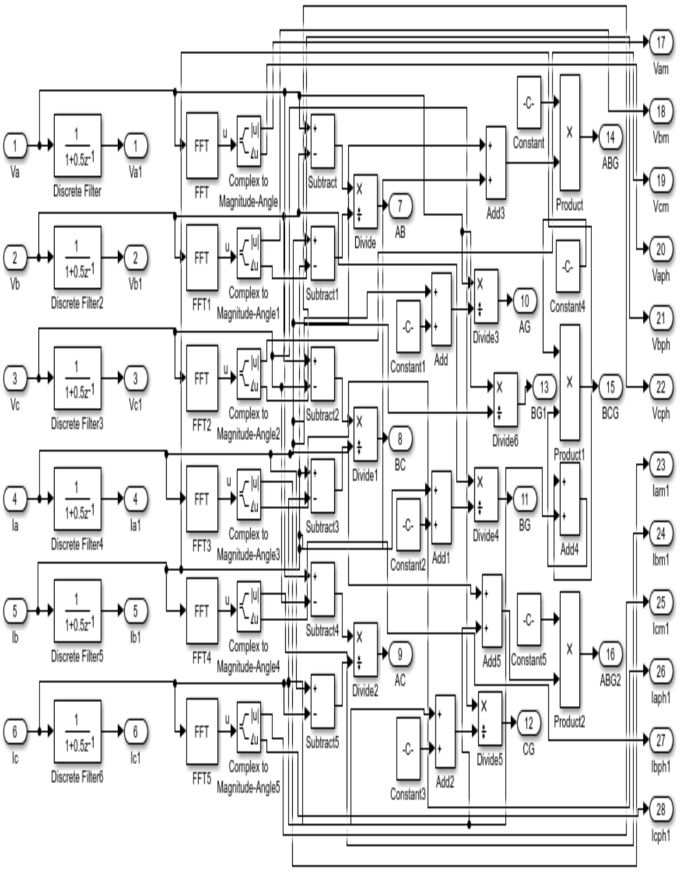

Figure 14: MATLAB/SIMULINK Impedance Relay Model

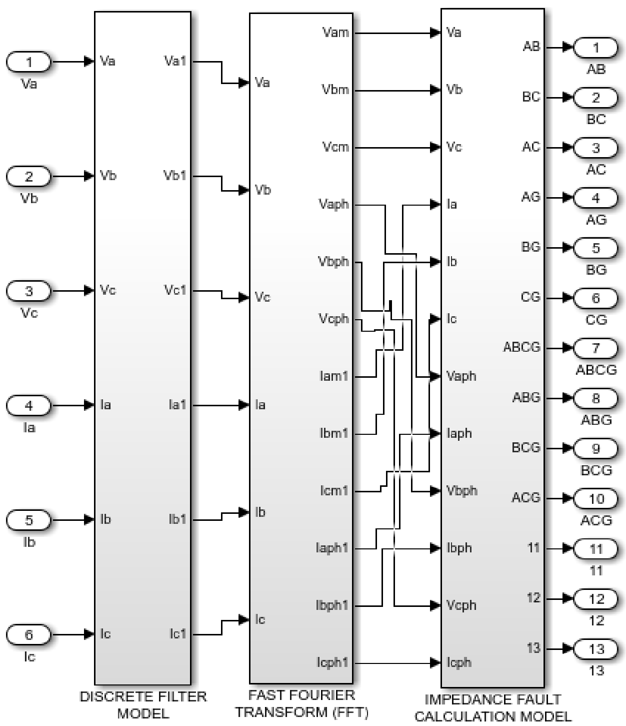

Figure 15: MATLAB/SIMULINK Impedance Relay Model Subsystem

III. RESULT DISCUSSION

Table 1: Per Unit Pre-fault Fault Parameters and their Values

S/N	V_a (e-2) pu	V_b (e-2) pu	V_c (e-2) pu	I_a (e-2) pu	I_b (e-2) pu	I_c (e-2) pu	Condition
1	1.8	1,8	1.8	0.2	0.2	0.2	No Fault
2	10.0	8.0	15.0	350	100	80	A – G
3	200	100	225	1800	1000	1500	AB – G
4	25	10	9	300	300	0.0	A – B
5	0.0	0.0	0.0	200	200	200	ABC - G

Table 2: Transmission line parameters

S/N	TRANSMISSION LINE PARAMETERS	VALUES
1	Line Length	150Km
2	Nominal Frequency F	50Hz
3	Line Resistance $R_1 = R_2$	0.01143
4	Line Inductance $L_1 = L_2$	8.684E-4
5	Line Capacitance $C_1 = C_2$	1.3426E-8
6	Zero Sequence Resistance R_0	0.2467
7	Zero Sequence Inductance L_0	3.0886E-3
8	Zero Sequence CapacitanceC_0	8,5885E-9
9	Positive Sequence Impedance Z_1	0.1867
10	Zero Sequence Impedance Z_0	0.7083
11	Line Impedance Z_L	1.1930
12	Relay Set Impedance Z_r	1.1900

Figures 6 to 13 are current and voltage signal waveforms of single line, double line, line to line and three phase faults obtained after simulation of the Matlab/Simulink Impedance Relay model connected to the Matlab/Simulink transmission line model. Each of them represents a particular type of fault that had occurred on the transmission line.

The Relay was able to trip the faults and the line was restored following the clearing of the faults after 1.2secs, 3.2secs, 3.0secs and 5.0secs respectively.

Table 1 show the pre-fault, fault current and voltage magnitudes obtained after simulation of the Matlab/Simulink Impedance Relay model connected to the Matlab/Simulink transmission line model. These magnitudes are evidence that fault occurred on the said transmission line.

IV. CONCUSION

Matlab/Simulink tool has been used for the modeling of a typical Onitsha to Enugu 330kV transmission line and the impedance relay model.

The application of the impedance relay model to the Onitsha – Enugu transmission and IEEE 9bus systems gave similar satisfactory results. Thus, a Matlab/Simulink impedance relay has been modeled.

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