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Location Of Faults on Nigeria 330kv Power Transmission Lines Using Traveling Wave

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Abstract- This paper studies the decrease in fault impedance of a transmission line when simulated for three-phase fault with an increase by 10Km in line distance from 10Km to 100Km using MATLAB/Simulink mathematical model of travelling wave. Fault location was performed on a 96Km 330KV Onitsha – Enugu Power system Transmission Line. The proposed method uses the measured fault voltage and current signals of the three phase lines as input to the fault detector and locator. The result show that, when the fault distance MATLAB/Simulink Travelling Wave fault location model is simulated for three-phase fault with geometrical increase in transmission line distance, the impedance and velocity of the travelling wave of the line decreases with sharp decrease and increase in voltage and current magnitudes respectively.

Indexed Terms- Traveling Wave, Power System, Transmission Line, Fault, Symmetrical.

I. INTRODUCTION

The power transmission line is the most frequently faulted element of a power transmission system. There are numerous possible causes of such faults. The causes include short circuits, faulty equipment, mis-operation, overload, aging of system components, lightning, and human errors. Faults causes short- or long-term power outages for customers and may lead to considerable losses. Thus, determination of fault location in power transmission lines is a major issue for electric utility industry. Fault location can be performed for the proper operation of power system protection devices or for the effective inspection of power transmission line. In the former case, fast localization is extremely important, while the accuracy may be limited only to correctly identifying the protection zone. In the latter case, it is important to precisely determine fault location. Accurate fault location can help in fast restoration of power, particularly on transmission lines with distributed loads [1]. Among the most important types of fault locators are: impedance and traveling wave locators. Impedance locators can be a part of power system protection device. The traveling wave locator works as an independent device [1][2]. The relay monitory line current and phase voltage can locate faults by using the equation 2 such that, when a fault occurs, the current magnitude increases and voltage decreases. This reduces the impedance. But under normal conditions, the impedance is high. This is also used to locate the fault on the transmission line.

There are various methods which can be employed for the location of fault on the power transmission line. Among them includes; artificial intelligence, signal processing, impedance, traveling wave etc. In this research, traveling wave method is employed for the location of fault distance.

II. METHODOLOGY

(A) Traveling Wave Method

The gradual development of line voltage may be attributed to a voltage wave travelling from the supply source end to the far end, and the related current wave will be accounted for by progressive charging of the line capacitances. Assume that a current I and a voltage V are established over a length x of the line in a relatively short time t. The back emf created by the magnetic flux produced by the current in this length of the line balances the emf V. The inductance of the length δx is Lδx (L is line inductance per unit length), hence the flux built up is ILδx and the back emf is the rate of building viz. IL δx/δt [2][3].
So we have

$$V = IL\frac{\delta x}{\delta t} = ILv \qquad (1)$$

Where v is the velocity of propagation of wave.
The current I carries a charge $I\delta t$ in time δt, and this charge remains on the line to charge it up to the

potential of V. Since the capacitance of length δx of the line is Cδx (C is the capacitance of the line per unit length), its charge is VCδx, so we have

$$I\delta t = VC\delta x \tag{2}$$

or

$$I = VC\frac{\delta x}{\delta t} = VCv \tag{3}$$

The switching of an emf V on to the line results therefore in a wave of current I and velocity v are given by equations (1) and (3). Dividing equation (1) by equation (3), we have

$$\frac{V}{I} = \frac{ILv}{VCv} = \frac{I}{V}\cdot\frac{L}{C} \tag{4}$$

or

$$\frac{V^2}{I^2} = \frac{L}{C} \tag{5}$$

or

$$\frac{V}{I} = \sqrt{\frac{L}{C}} = Z_n \tag{6}$$

The expression is a ratio of voltage V and current I which has the dimensions of impedance and is therefore here designated as surge impedance of the line. It is also called natural impedance because this impedance has nothing to do with the load impedance, but depends only on the line constants [2][3].

From equation (6) surge impedance Z_n which is the ratio of voltage and current having the dimension of impedance is thus:

$$Z_n = \frac{V^2}{I^2} = \frac{L}{C} \tag{7}$$

$$\text{Inductance } L = \frac{V^2C}{I^2} \tag{8}$$

$$\text{Capacitance } C = \frac{I^2L}{V^2} \tag{9}$$

(a) Propagation velocity v of travelling wave:

To get velocity of travelling wave, multiply equations (1) and (4)

$$VI = ILv \times VCv \tag{10}$$

$$VI = VILCv^2 \tag{11}$$

or

$$v^2 = \frac{1}{LC} \tag{12}$$

or

$$v = \sqrt{\frac{1}{LC}} \tag{13}$$

Where L is inductance of the line and C is the capacitance of the line v is the propagation velocity [1][2][3].

Figure 6 is used to simulate pre-fault and three phase faults. The results show that there is shape decrease in voltage magnitude from x to y and increase in current magnitude from a to b.

Figure 2 and 3 are pre-fault voltage and current signal waveforms that show no fault on the line. But figure 4 and 5 represents three phase fault voltage and current signal waveforms that show that fault occurred on the line.

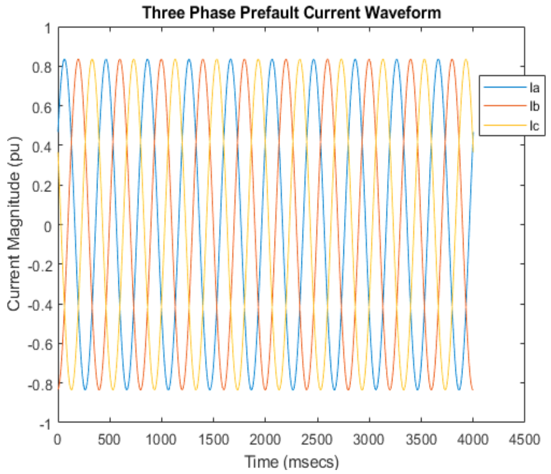


Figure 1: Three Phase Pre-fault Voltage Waveform

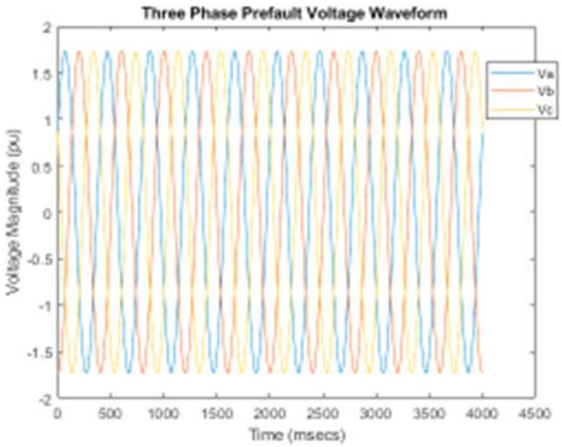


Figure 2: Three Phase Pre-fault Voltage Waveform

The occurred fault distance is located using the travelling wave MATLAB/Simulink model of figure 4.

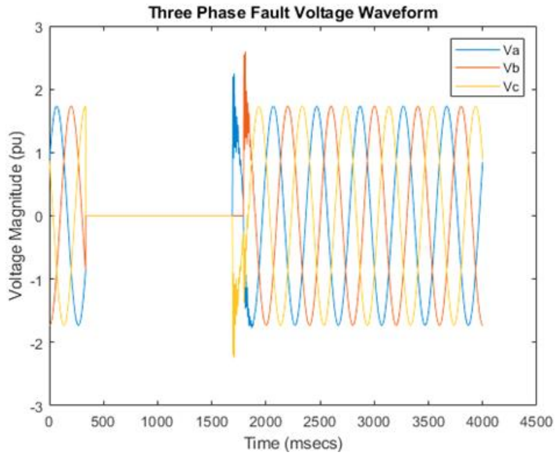


Figure 3: Three Phase Pre-fault Voltage Waveform

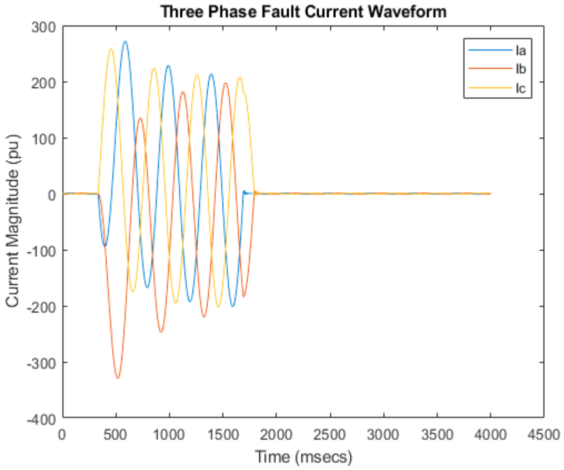


Figure 4: Three Phase Pre-fault Voltage Waveform

(b) Double Ended Fault Location on the transmission line based on travelling wave.

The most obvious and robust travelling wave-based fault location is based on a two ended principle as shown is figure below and has been implemented in various fault location and protection devices [3][4].

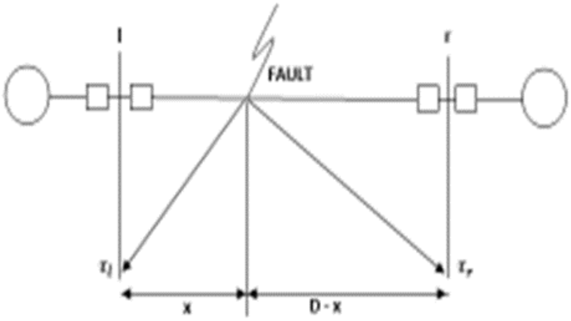


Figure 5: Double ended fault location

(c) based on time difference of first arrival times. The arrival times of the traveling waves on both ends of the line are compared and the fault location x is calculated according to the following formula:

$$x = \frac{(D+(\tau_l-\tau_r)v)}{2} \quad (14)$$

Where,

D = Total length of the line

τ_l = Departure time at the remote end

τ_r = Arrival time at the local end

v = Propagation velocity

(d) Simulink modeling of the traveling wave fault location equation.

Equation (14) is modeled using MATLAB/SIMULINK for location of any type of fault on the transmission line. Figure 2 and 3 are propagation velocity and fault location models.

$$\text{Velocity } v = \sqrt{\frac{1}{LC}} \quad (15)$$

But

$$\text{Relay impedance } Z_r = \frac{V^2}{I^2} = \frac{L}{C} \quad (16)$$

$$\text{Inductance } L = \frac{V^2C}{I^2} \quad (17)$$

$$\text{Capacitance } C = \frac{I^2L}{V^2} \quad (18)$$

Therefore,

$$\text{velocity } v = \sqrt{\frac{1}{\left(\frac{V^2C}{I^2}\right)\times\left(\frac{I^2L}{V^2}\right)}} \quad (19)$$

(B) Location of Fault

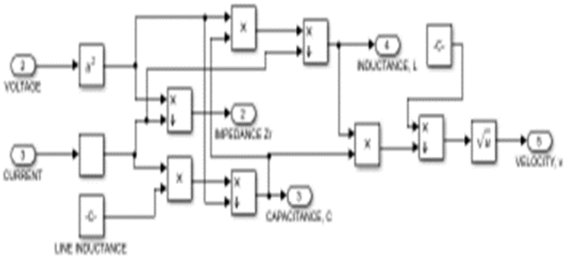


Figure 6: Traveling Wave Propagation Velocity Model

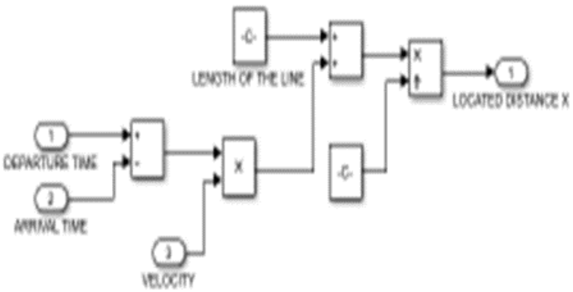


Figure 7: Traveling Wave Fault Location Model

$$x = \frac{(D+(\tau_l - \tau_r)v)}{2} \qquad (20)$$

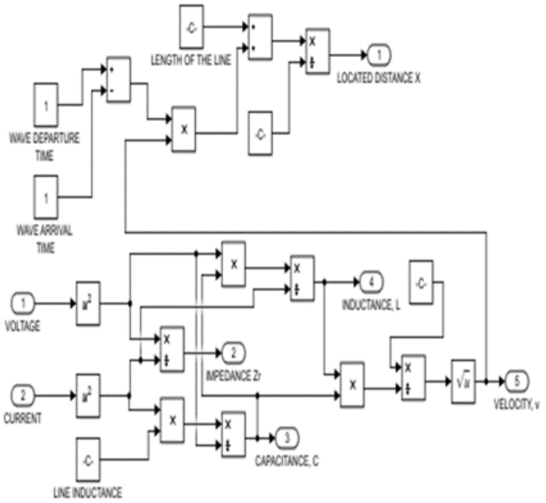


Figure 8: Traveling Wave Fault Location Model

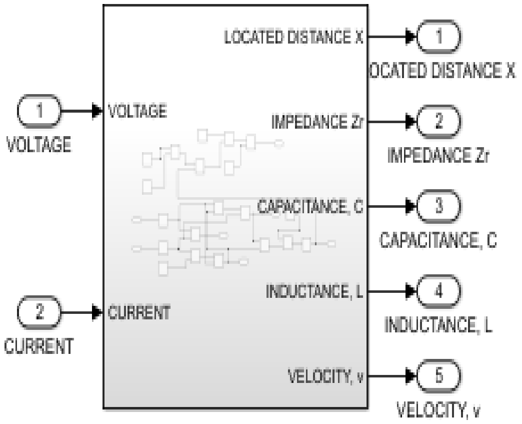


Figure 9: Subsystem of Traveling Wave Fault Location Model

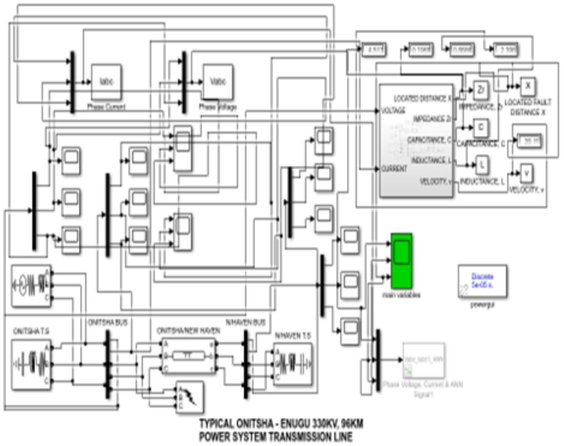


Figure 10: Single Onitsha – Enugu 330KV 96Km Transmission Line

(a) Zones of Protection

The zone on which the fault occurred can be determined using the distance protection zoning system shown below.

Zone 1 setting on the transmission line is 80% of the line distance, Zone 2 setting on the transmission line is 120% of the line distance, and Zone 3 setting on the transmission line is 240% of the total line distance.

Zone 1 is meant to protect the primary line and provide fastest protection because there is no international time delay associated with it. Its operating time can be one cycle.

Zone 1 reach = 0.8 x Total length of the transmission line = 0.8 x 96Km = 76.8Km

Zone 2 reach = 1.2 x Total length of the transmission line = 1.2 x 96Km = 115.2Km

Zone 3 reach = 2.5 x Total length of the transmission line = 2.5 x 96Km = 240Km

The located fault distance is seen on the zone of protection discussed below [4][6].

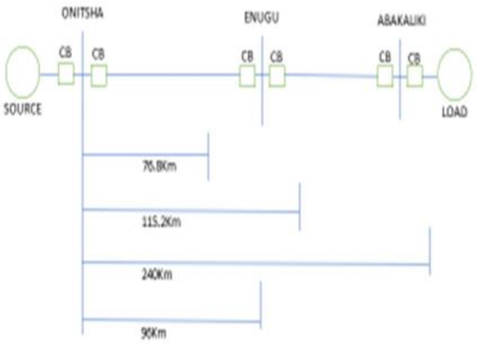


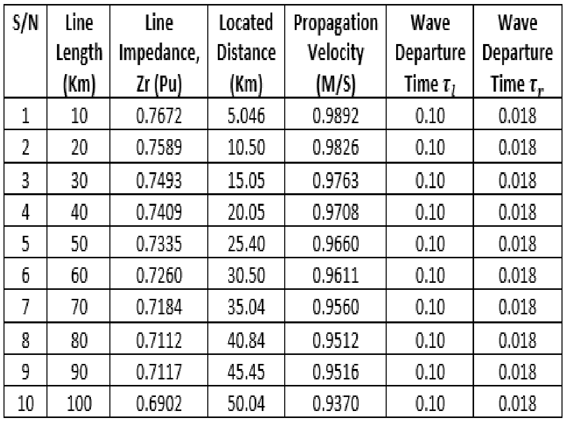
Figure 11: Single Onitsha – Enugu 330KV 96Km Transmission Line

Using the MATLAB/SIMULINK modeled equations (6) to (12), we can locate the various symmetrical and unsymmetrical faults using their fault voltage and current parameters.

III. RESULTS ANALYSIS

(a) Determination of Fault Distance through Zoning
The Onitsha – Enugu Power System transmission line is a 96km power line. In this section, the line is made 10km for ten possible outcomes. Travelling Wave MATLAB/Simulink model is used to locate three-phase (A-B-C) fault distance on each of 10km lines. The results obtained, its analysis is shown and discussed below.

Table 1: Location of Three-Phase Fault (A-B-C) Distance using MATLAB/Simulink Traveling Wave Model



S/N	Line Length (Km)	Line Impedance, Zr (Pu)	Located Distance (Km)	Propagation Velocity (M/S)	Wave Departure Time τ_l	Wave Departure Time τ_r
1	10	0.7672	5.046	0.9892	0.10	0.018
2	20	0.7589	10.50	0.9826	0.10	0.018
3	30	0.7493	15.05	0.9763	0.10	0.018
4	40	0.7409	20.05	0.9708	0.10	0.018
5	50	0.7335	25.40	0.9660	0.10	0.018
6	60	0.7260	30.50	0.9611	0.10	0.018
7	70	0.7184	35.04	0.9560	0.10	0.018
8	80	0.7112	40.84	0.9512	0.10	0.018
9	90	0.7117	45.45	0.9516	0.10	0.018
10	100	0.6902	50.04	0.9370	0.10	0.018

Table 1 illustrates the results obtained when traveling wave mathematical model is modeled using MATLAB/Simulink tool and employed for the location of fault distance on Onitsha – Enugu 330KV power system transmission line. Here, only three-phase fault result is shown since it will very ambiguous to show all the results obtained when the traveling wave model is employed for both symmetrical and unsymmetrical faults.

The table 1 is the simulation results obtained when the three-phase fault distance location MATLAB/Simulink model of figure 4 is simulated for symmetrical (three-phase fault) fault.

The results show that, as the line length increases, the located fault distance increases with decrease in impedance and the propagation velocity of the wave signals. This is because of the change in topography of the line and change in incident point of fault [1][2].

This is in line with the standard that, the shorter the distance of the power lines, the shorter the line length, due to the closeness of the traveling waves traveling through the power lines and which does not experience much disturbance on the line, the more stable and steady the impedance of the line. But, the longer the length of the line, the lesser the impedance and the more the line is exposed to various disturbances such as line losses, symmetrical and unsymmetrical faults, effects of wind force etc. [5][6][7].

REFERENCES

[1] Gupta S. K. (2009) Power System Engineering January 2009’’. 4232/1, Ansari Road, Dariyaganj, Delhi-110002 ISBN: 978-81-88114-91-7.

[2] Anazia E. A, Ogboh V. C., Anionovo U.E. (2020). Time – Frequency Analysis Technique for Fault Investigation on Power System Transmission Lines. International Journal of Engineering Inventions, 9(6), 18 25.

[3] Ogboh, V., Ezeakudo, E., & Anazia, E. (2019). A MATLAB Approach for Fault Location on Power System Transmission Line Using Traveling Wave Method. Ire Journals Ire Journals, 3(3), 2456-8880.

[4] Mustapha, A. H. B., Hamdan, R., Noh, F. M., Zambri, N. A., Jalil, M. H. A., Morsin, M., & Basar, M. F. ‘’Fault location identification of double circuit transmission line using discrete wavelet transforms. Indonesian Journal of Electrical Engineering and Computer Science, 15(3), 1356-1365.

[5] Saritha M., Viji C., Aravind K., Joel O. B., Linu B., Juhina A., Priya S (2015). Fault Detection and Location in Transmission Line using Pole Climbing Robort’’. International Journal of Engineering Science & Research Technology. ISSN: 2277-9655. March, 2015.

[6] Ogboh V. C, Ezechukwu O. A, Madueme T. C. (2019) Analysis of Fault Detection Algorithm for

Power System Transmission Lines Using DFT And FFT’’. Ire Journals Volume 3 Issue |3 | ISSN: 2456-8880 Ire 1701668 Iconic Research and Engineering Journals 142.