A MATLAB Approach for Fault Location on Power System Transmission Line Using Traveling Wave Method

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***Abstract* - Traveling waves is generated on power system transmission line due to the constant propagation of electrical voltage and current in both directions of the line. Faults on power system transmission line was detected and located using a fault distance location system modeled using MATLAB 2016. The model was simulated with the transmission line parameters. Also phase A – G fault was simulated. The result show that, the phase A – G fault occurred at a distance point of 40km with a fault current of 0.48pu (figure 9) and 0.085pu (figure 10) corresponding with the fault distance and higher than the fault current of the line when the fault has not occurred.**

Indexed Terms: MATLAB / Simulink, Travelling wave, transmission line

I. INTRODUCTION

Considering the components of an electrical power system which are generation, transmission and distribution units, there is need for growth in the capacity of each units. This is because, the demand of electric power is also growing very faster every day.

This growth has resulted to the building of very complex power system networks which in normal condition operates under steady states. But due to certain natural, artificial, temporal and permanent disturbances which occurs in the power system causes severe or less-severe damages to the network. These disturbances are regarded as faults which can be categorized as balanced and unbalanced faults.

Whenever these faults occur on the network, they always result to inflow of large amount of current and reduction in voltage of the power system network component. The large of current is cable of causing severe or permanent damage to the network equipment. These currents can be interrupted promptly, minimized controllably or eliminated completely by using sophisticated protection equipment.

II. METHODOLOGY

A. Transmission line Equation

The general transmission line equation called Telegraph equation was formulated by Oliver Heaviside between 1850 and 1925. The equation was used for the first time to investigate the disturbance on the telegraph wires [1][2].

Assuming the line segment of dx with parameters of line resistance (R), conductance (G), inductance (L) and capacitance (C), all in per unit length, the line constants for the segments becomes Rdx, Gdx, Ldx and Cdx. The electric flux φ and magnetic flux ∅ created by the electromagnetic wave on the line which causes instantaneous voltage u(x, t) and current i(x, t) are given as;

$$d\varphi\ (t) = u(x,t)Cdx \qquad 1$$

$$d\emptyset\ (t) = i(x,t)Ldx \qquad 2$$

The voltage drop in the positive direction of distance dx from x can be obtained as;

$$u(x,t) - u(x+dx,t) = -du(x,t) \qquad 3$$

$$= \frac{\partial u(x,t)}{\partial x}dx = \left(R + L\frac{\partial}{\partial t}\right)i(x,t) \qquad 4$$

Eliminating dx, we have

$$\frac{\partial u(x,t)}{\partial x} = -L\frac{\partial i(x,t)}{\partial t} - Ri(x,t) \qquad 5$$

The current flowing through the conductor and charging the capacitor C can be obtained using;

$$i(x,t) - i(x+dx,t) = -di(x,t) \qquad 6$$

$$= \frac{\partial i(x,t)}{\partial x}dx \qquad 7$$

$$= \left(G + C\frac{\partial}{\partial t}\right)u(x,t)dx \qquad 8$$

$$\frac{\partial i(x,t)}{\partial x} = -C\frac{\partial i(x,t)}{\partial x} - Gu(x,t) \qquad 9$$

These negative signs in the equation above are caused due decrease in amplitude of current and voltage waves which propagates in the positive x – direction and later increase x[1].

$$Z = R + \frac{\partial L(x,t)}{\partial t} \qquad 10$$

$$Y = G + \frac{\partial C(x,t)}{\partial t} \qquad 11$$

However, substituting equations 10 and 11 into the above equations 5 and 8 respectively and take the derivatives with respect to x, we will obtain that,

$$\frac{\partial^2 i(x,t)}{\partial x^2} = -Y\frac{\partial u(x,t)}{\partial t} = YZi(x,t) \qquad 12$$

$$= \gamma^2 i(x,t) \qquad 13$$

$$\frac{\partial^2 u(x,t)}{\partial x^2} = -Z\frac{\partial i(x,t)}{\partial t} = YZu(x,t) \qquad 14$$

$$= \gamma^2 u(x,t) \qquad 15$$

Thus, figure 1 shows the representation of the above transmission line traveling wave parameters.

Giving that

$$\gamma = \sqrt{ZY}\,\alpha + j\beta \qquad 16$$

Where γ is called a complex quantity known as propagation constant.

Also, α is called the attenuation constant which influences the amplitude of the traveling wave.

β is called the phase constant which influences the phase shift of the traveling wave[2].

Characteristic impedance of the line can be obtained using;

$$Z = \sqrt{\frac{R + L\frac{\partial}{\partial t}}{G + C\frac{\partial}{\partial t}}} \qquad 17$$

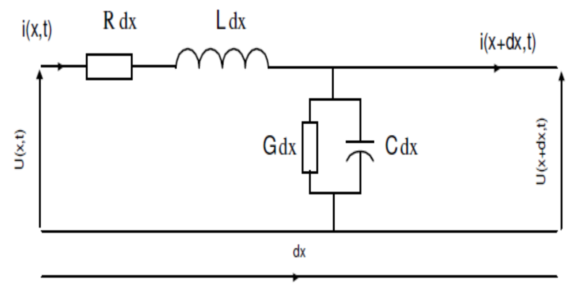

Figure 1: Single phase transmission line model

B. The Lossless Line

Considering the propagation of traveling waves of voltage and current on a single – phase transmission line, the series resistance R and the parallel conductance, G are zero while the inductance and capacitance are constants. Therefore, the transmission line equations becomes;

$$\frac{\partial u}{\partial x} = -L\frac{\partial i}{\partial t} \qquad 18$$

$$\frac{\partial i}{\partial x} = -C\frac{\partial u}{\partial t} \qquad 19$$

More so, the traveling wave propagation is steady state and not damping, therefore;

$$u = Z_0 i \qquad 20$$

And equations 18 and 19 becomes;

$$Z_0\frac{\partial i}{\partial x} = -L\frac{\partial i}{\partial t} \qquad 21$$

$$\frac{\partial i}{\partial x} = Z_0 C\frac{\partial i}{\partial t} \qquad 22$$

Dividing equation 21 by 22, we have that,

$$Z_0 = \sqrt{\frac{L}{C}} \qquad 23$$

Z_0 is called the characteristic impedance of the lossless line.

This impedance helps the current and voltage wave to travel through the line without changing their wave shapes [2][3].

Thus, the traveling wave equation of lossless line is given by;

$$\frac{\partial^2 u}{\partial x^2} = LCu \qquad 24$$

From the above equation of lossless line, we can obtain the traveling wave propagation speed v from the voltage and current equations given below;

$$u(x,t) = A_1(t)e^{\frac{x}{v}} + A_2(t)e^{-\frac{x}{v}} \qquad 25$$

$$i(x,t) = -\frac{1}{Z_0}(A_1(t)e^{\frac{x}{v}} + A_2(t)e^{-\frac{x}{v}}) \qquad 26$$

$$v = \frac{1}{\sqrt{LC}} \qquad 27$$

Equation 27 is called traveling wave propagation speed or velocity for forward (e_f and i_f) and reversed (e_r and i_r) waves. Where e and i are voltage and current waves on the line [2] [3].

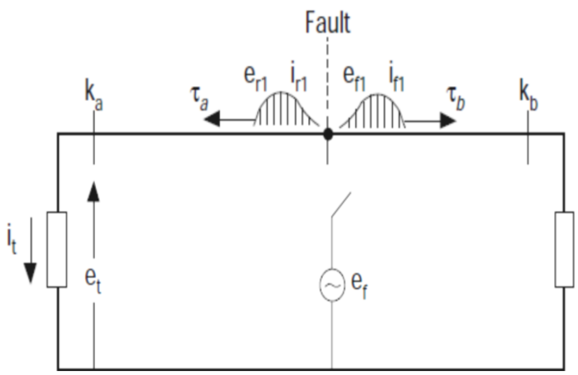

Figure 2: Travelling voltage and current wave ends

Where K_a and K_b are reflection coefficients which can be determined using the characteristic impedance ratios at the termination points.

τ_a and τ_b represents the traveling wave time from the fault point to the termination points of the waves. They can be obtained using the length l of the line and the distance x.

The distance of the fault point can be located or obtained using;

$$x = \frac{l - c(\tau_a - \tau_b)}{2} \qquad 28$$

C = 299.79m/secs and is called the wave propagation speed

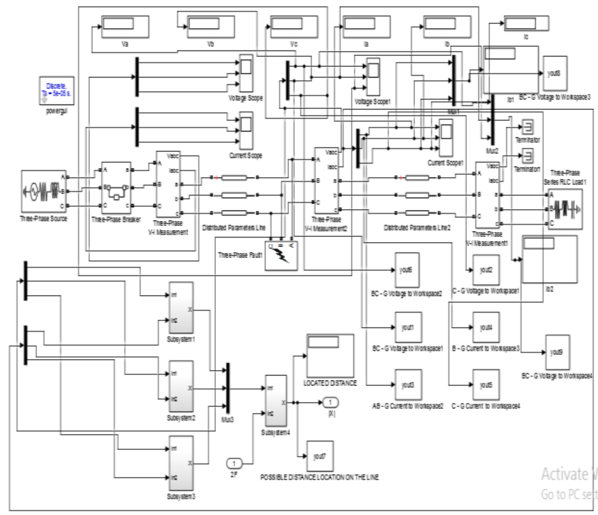

Figure3: Matlab/Simulink Model of 132KV Onitsha – Awka – Enugu Transmission Line/ Travelling Wave Fault Location Distance

Figure 3 is the 132KV, 96Km power system transmission line of Onitsha – Awka – Enugu modeled with Matlab/Simulink 2016.

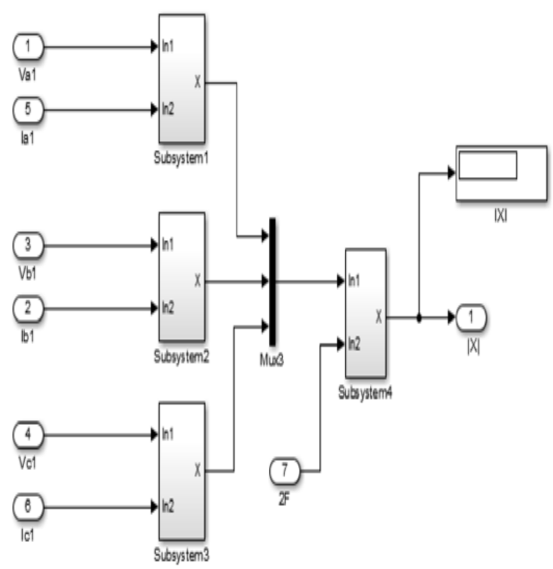

Figure 4: Matlab/Simulink Distance fault location computing system

V_{a1}, V_{b1}, V_{c1}, I_{a1}, I_{b1}, and I_{c1} are the voltage and current of three phases of the transmission line which are used as inputs signals of the Distance Fault Location System of figure 4.

When fault occurs on the transmission line, the voltage of faulted line suddenly reduces to a low value and the current on that line will largely increase. This sudden change produces a high frequency electromagnetic impulse called traveling wave (TW) [2] [3].

These traveling waves propagates away from the point of fault in both directions at the speed almost equal to the speed of light. The fault point can be located by picking the fault current and voltage signals filter them or use them without filtering as inputs of the traveling wave mathematical Matlab/Simulink model built for the location of fault on the Onitsha – Awka – Enugu transmission line [2] [3] [4] [5].

The transmission line modeled with Matlab/Simulink 2016 representing Onitsha – Awka – Enugu transmission line is shown on figure 3. This transmission line is modeled using the line parameters.

Also, the traveling wave fault locating system was modeled using the same Matlab/Simulink 2016 and is shown on figure 4.

Thus, when the traveling wave fault location system is simulated it shows the location of the fault (fault distance) on the line from the sending end with respect to the time of arrival of the traveling wave in the two ends of the transmission line [2] [3] [4] [5].

III. RESULTS AND DISCUSSION

The above Onitsha – Awka – Enugu transmission line parameters were used to model and simulate the Matlab/Simulink 2016 modeled transmission line. Below are the simulation results.

Figures 5 and 6 are the voltage and current waveform obtained when the modeled transmission line is at no fault condition. Figure 7 is output waveform of the distance location Matlab/Simulink block diagram built using travelling wave fault location distance equation shown on section 3 as equation…

Also, figures 8 and 9 are the voltage and current waveform obtained when the modeled transmission line is on phase A – G fault condition. Figure 10 is output waveform of the distance location Matlab/Simulink block diagram built using travelling wave fault location distance equation shown on section 3 as equation…

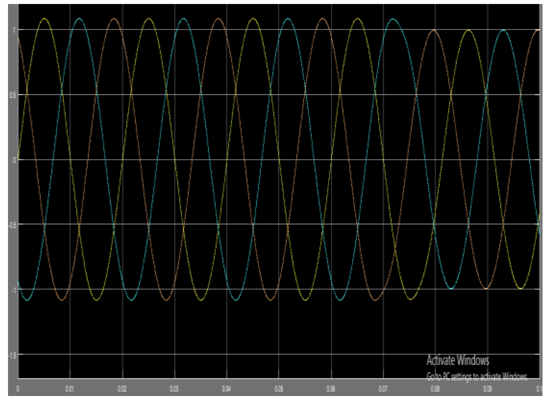

Figure 5: No fault Voltage waveform

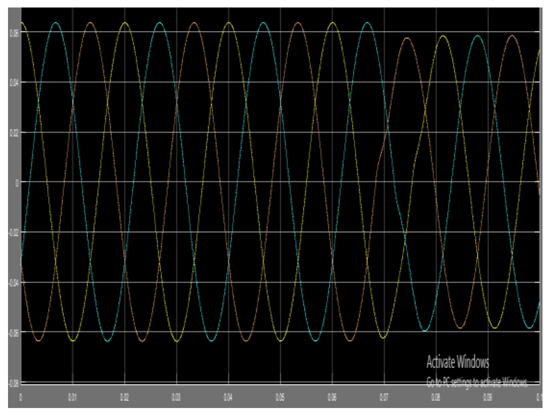

Figure 6: No fault Current Waveform

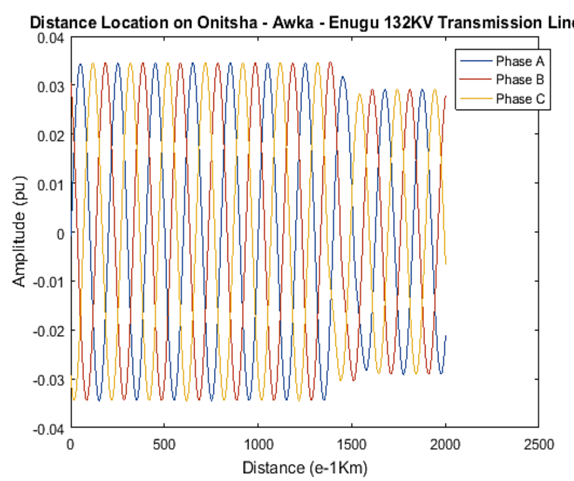

Figure 7: No fault Location Distance on 132KV 96Km Onitsha – Awka – Enugu Transmission Line

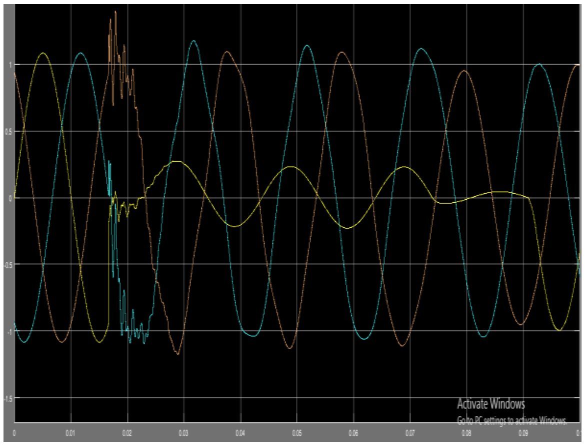

Figure 8: 132KV 96Km Onitsha – Awka – Enugu Transmission Line Phase A – G fault Voltage Waveform. [6]

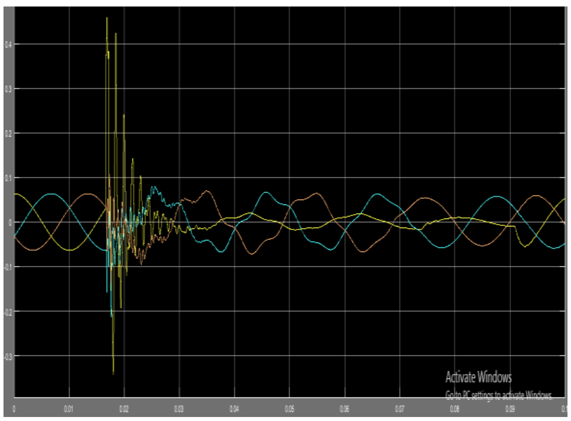

Figure 9: 132KV 96Km Onitsha – Awka – Enugu Transmission Line Phase A – G fault Current Waveform. [6]

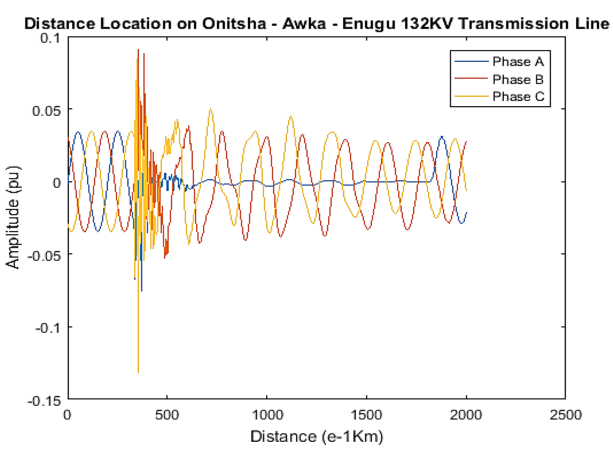

Figure 10: Fault Location Distance on the 132KV 96Km Onitsha – Awka – Enugu Transmission line

Table 1: Per Unit No fault phase voltage and current values

S/No	Phase	Voltage (Pu)	Current(Pu)	Location Distance (Km)
1	A	1.18	0.06	-
2	B	1.18	0.06	-
3	C	1.18	0.06	-

Table 2: Per Unit Phase A – G fault voltage and current values

S/No	Phase	Voltage (Pu)	Current(Pu)	Location Distance (Km)
1	A	0.18	0.48	40
2	B	0.48	0.17	-
3	C	1.48	0.15	-

Table 1 is a representation of distance location, voltage and current values obtained at No fault and faulty conditions of the said transmission line respectively.

From table 1, the phase values of three phases are the same meaning that there is no fault on the line as seen on figures 3 and 4. While on table 2, the phase values of three phases are the different which means that there is fault on the line as seen on figures 6 and 7. Also, on the same table 2, the distance location of fault point at 40Km was shown and the phase A current is higher than other phase currents. This corresponds to the 40Km phase A – G fault distance located on the transmission line and shown on figure 9 and 10.

IV. CONCLUSSION

This paper has been able to illustrate one of the ways fault occurred on the transmission line can be detected and located using a fault locating distance system modeled using MATLAB 2016 (Figure 4).

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