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Non-Iterative Impedance Method For Fault Distance Detection On Transmission Lines

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Abstract— **In this paper, a non-iterative impedance method for fault location on a three phase transmission line is presented. The study used the one-end positive sequence reactance fault detection method in the derivation of the analytical model for estimating the distance of a fault on a transmission line from a given terminal of the line. The transmission line and the requisite analytical models were modeled in Simulink and then simulated based on the data from a selected case study transmission line. The result of the simulation showed that for the different fault types considered ion the transmission line, the maximum fault location estimation error witnessed was 8.6 % below the actual value. The impedance method has root mean square error (RMSE) of 1.625454 km and coefficient of determination (r2) value of 0.998. Essentially, the impedance method can be used to trace the fault location to the nearest 1.6 km from the actual fault location.**

Keywords — Impedance Method, Transmission Line, Fault Distance Detection, Fault Current, Fault Type

I. INTRODUCTION

Electricity produced by a power plant is delivered to load centers and electricity consumers through transmission held by huge transmission towers. During normal operation, a power system is in balanced condition [1,2,3,4,5]. Abnormal scenarios occur due to fault. Fault in a power system can be created by natural events such as falling of a tree, wind, and storm damaging a transmission line, and sometimes by mechanical failure of transformers and other equipment in the system [6,7]. The introduction of new marketing concepts such as deregulation has increased the need for reliable and uninterrupted supply of electric power to the end users who are very sensitive to power outages [8]. One of the most important factors that hinder the continuous supply of electricity and power is a fault in the power system [9]. Any abnormal flow of current in a power system's components is called a fault [10,11]. These faults cannot be completely avoided since a portion of these faults also occur due to natural reasons which are beyond the control of mankind. Hence, it is very important to have a well-coordinated protection system that detects any kind of abnormal flow of current in the power system, identifies the type of fault and then accurately locates the position of the fault in the power system. The faults are usually taken care of by devices that detect the occurrence of a fault and eventually isolate the faulted section from the rest of the power system. The automatic location of faults can greatly enhance the systems reliability because the faster we restore power, the more money and valuable time we save. Hence,many utilities are implementing fault locating devices in their power quality monitoring systems [9] that are equipped with Global Information Systems for easy location of these faults [12,13,14,15,16]. Fault location techniques can be broadly classified into intelligence based, impedance measurement based and travelling wave phenomenon based methods. In this paper, the non-iterative impedance method for fault distance detection on transmission lines. This method uses a mathematical model with closed form solution for determining the distance of the fault from the transmission line terminal. Sample faulted transmission line was used as case study and the faulted line was modeled and simulated suing MATHLAB software.

II. METHODOLOGY: IMPEDANCE BASED METHOD

In this paper, a three phase fault is assumed to have occurred on a330 kV transmission line. One line diagram of a single three phase transmission line system having two generators, S and R with a fault at a distance m from S is shown in Figure 1. The phasor voltage and current are assumed to be available from each of the two ends of the single transmission line.

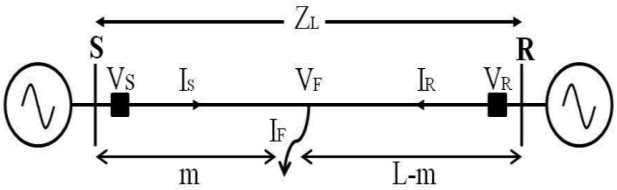

Figure 1: One line diagram of a single three phase transmission line system having two generators, S and R with a fault at a distance m from S

(Source: [17])

Each terminal of the transmission line (TL) is equipped with intelligent electronic device (IED). The measured terminal voltages are denoted as V_S and V_R, the measured current are denoted as I_S and I_R, the impedance of the transmission line is denoted as Z_L. The length of the transmission line is L and the a fault occurs on the line at a distance of m from terminal S, hence, fault location is a distance of L-m from terminal R. Also, V_F denotes the fault voltage and I_F demotes the fault current at the fault location. In this paper, fault detection method used is the one-end positive sequence reactance method. The drop in the voltage from S, the source terminal to the fault location for positive, negative and zero sequence is given as follows;

$$V_{s1} = mZ_{L1}I_{s1} + V_{F1} \quad (1)$$

$$V_{s2} = mZ_{L2}I_{s2} + V_{F2} \quad (2)$$

$$V_{s0} = mZ_{L0}I_{s0} + V_{F0} \quad (3)$$

When the threeequations are added , they give;

$$V_{sa} = mZ_{L1}I_{S1} + mZ_{L2}I_{S2} + mZ_{L0}I_{S0} + V_{Fa} \quad (4)$$

Now, for phase A to ground (A-G) fault, $V_{Fa} = R_F I_F$ and in this case it is assumed that Z_{L1} and Z_{L2} and $I_{S1} = I_{S2} = I_{S0} = \frac{1}{3}I_F$, then Equation (4) becomes;

$$V_{Sa} = mZ_{L1}(I_{Sa} + kI_{S0}) + R_F I_F \quad (5)$$

Where $k = \frac{Z_{L0}-Z_{L1}}{Z_{L1}}$. Furthermore, the sending end voltage, V_S and the sending end current, I_S are given as;

$$V_s = V_{sa} \quad (6)$$

$$I_S = I_{Sa} + kI_{So} \quad (7)$$

Hence;

$$V_s = mZ_{L1}I_S + R_F I_F \quad (8)$$

Again, the apparent reactance measured at terminal S is given as;

$$\frac{V_S}{I_S} = mZ_{L1} + R_F\frac{I_F}{I_S} \quad (9)$$

The selection of V_s and $I_s$is dependent on the type offault as presented in Table 1.

Table 1: Selection of measurements for different fault types

Fault Type	V_S	I_s
A-G	V_a	$I_a + kI_0$
B-G	V_b	$I_b + kI_0$
C-G	V_c	$I_c + kI_0$
A-B or A-B-G	V_{ab}	I_{ab}
B-C or B-C-G	V_{bc}	I_{bc}
C-A or C-A-G	V_{ca}	I_{ca}
A-B-C or A-B-C-G	Any of V_{ab}, V_{bc}, V_{ca}	Any of I_{ab}, I_{bc}, I_{ca}

(Source: [17])

Now, the imaginary part of Z_{L1} is denoted as $Im(Z_{L1})$which is the same as the reactance X_{L1}. When the effect of fault resistance, only the imagery part of $\frac{V_S}{I_S}$ in Equation (9) is computed. Hence, when R_F is negligible, m can be determined from Equation (9) as follows;

$$m = \frac{Im\left(\frac{V_S}{I_S}\right)}{Z_{L1}} = = \frac{Im\left(\frac{V_S}{I_S}\right)}{X_{L1}} \quad (10)$$

III. RESULTS AND DISCUSSION

The simulink model the case study transmission line connecting Ikot-Abasi generation station and Afaha-Ube transmission sub-station is shown in Figure 2.

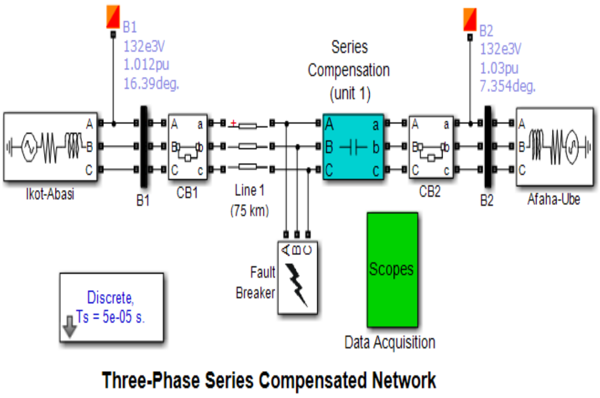

Figure 2; Simulink model the case study transmission line connecting Ikot-Abasi generation station and Afaha-Ube transmission sub-station

The parameters for Ikot-Abasi generation station is shown in Figure 3. The parameters for the Afaha-Ube Substation are shown in Figure 4 while the 3-phase fault parameters are shown in Figure 5.

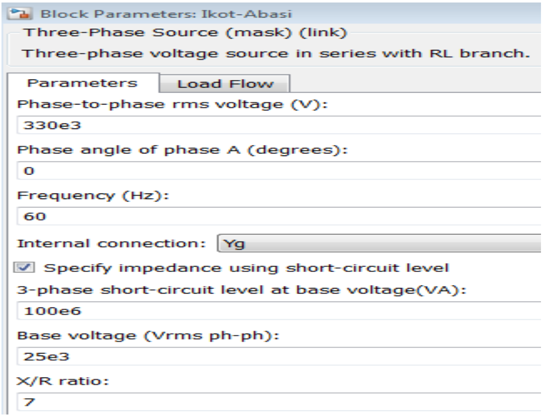

Figure 3; Ikot Abasi Generation station parameters

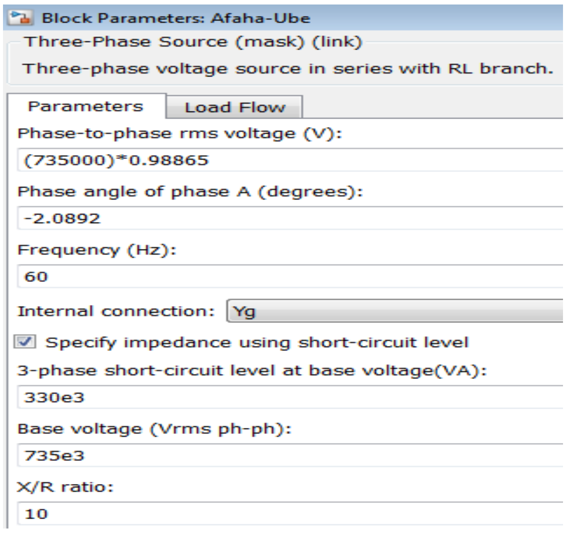

Figure 4: Afaha-Ube substation parameters.

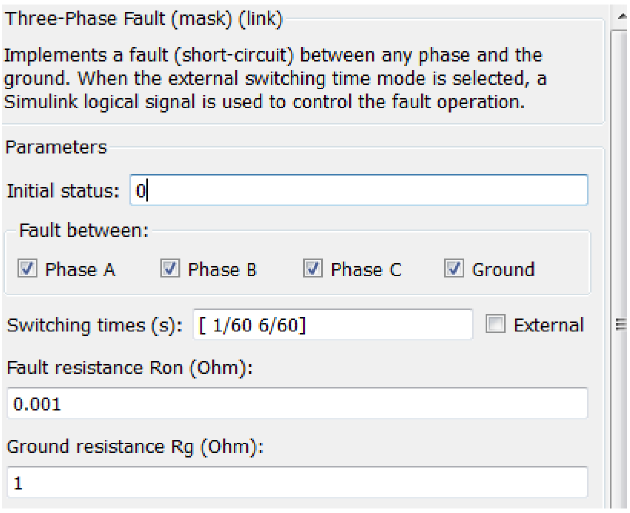

Figure 5: The 3-phase fault parameters

The data on High Impedance Fault (HIF) current and voltage with respect to time were generated when a 3-Phase HIF was introduced into the Simulink model as shown in Figure 5. The current and voltage plots when HIF occurs in the transmission line are shown in Figure 6 and Figure 7 respectively. Finally, Table 2 shows the percentage error in fault distance estimation using the impedance method. The results showed that for the different fault types considered ion the transmission line, the maximum fault location estimation error witnessed was 8.6 % below the actual value. The impedance method has root mean square error (RMSE) of 1.625454 km and coefficient of determination (r^2) value of 0.998. Essentially, the impedance method can be used to trace the fault location to the nearest 1.6 km from the actual fault location.

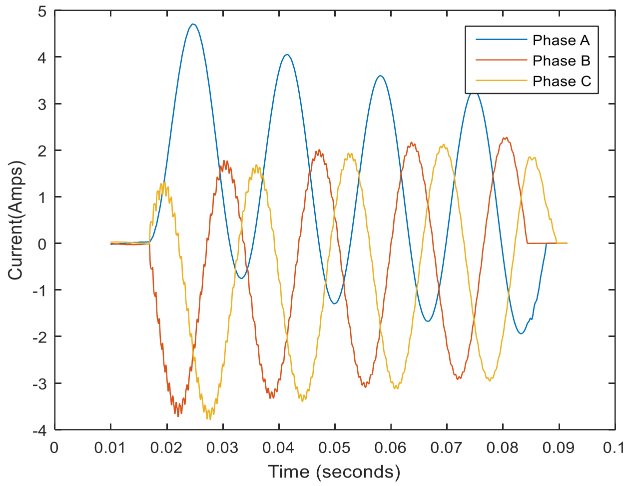

Figure 6; Current of the High Impedance Faults

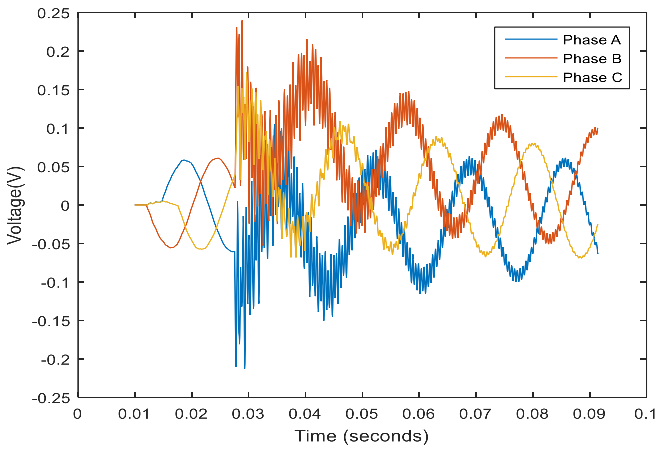

Figure 7; Voltages of high impedance faults

Table 2: Percentage error in fault distance using impedance method

Fault type	Actual distance (km)	Impedance method (km)	% error with impedance method
A-G	**20**	**18.28**	**-8.6**
B-G	**16.36**	15.46	**-5.50122**
AB-G	**36.33**	34.37	**-5.39499**
ABC-G	**35.3**	33.58	**-4.87252**
	r^2 = 0.998 and RMSE = 1.625454 km		

IV. CONCLUSION

A non-iterative impedance method for fault location on a three phase transmission line is presented. The analytical model for calculating the fault location (distance) from one end of the transmission line is also presented. In the analysis, the one-end positive sequence reactance fault detection method was used. The case study transmission line data were modeled and simulated in Simulink and the results are presented and discussed. In all, the impedance method was effective in estimating the fault location with minimal error.

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