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Faults Modelling And Evaluation For A 330 KV Transmission Line Network

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Abstract— **In this paper, faults modelling and evaluation for the 330 KV transmission line network in the Niger Delta region of Nigeria is presented. Specifically, the single line to ground fault, the two-phase to ground fault and the two-phase line-to-line fault are considered. The analytical model for phase current and voltages of the line in presence fault are presented along with the Simulink model of the transmission line with each of the listed faults. The three transmission line fault models were simulated using Matlab software such that the single line to ground fault was introduced to Phase C at the 4th second (that is time =4 s). The results show that before the faults was introduced the waveform of the phase current and voltage were stable but when the fault was introduced to Phase C at 4s, the current in Phase C increased significantly while the voltage decreased to 0 volt which cause unhealthy state in the power network. Similarly, before the two-Phase (Phase A and B) line-to-line fault was introduced at the 8 s in the simulation time the waveform of the current and voltage were stable but when the fault was introduced the current of Phase A and Phase B increased and the voltage decreased to 0 volt (for phase A and phase B) which cause unhealthy state in the power network. In addition, similar effects were observed when the two-phase to ground fault was introduced to Phase B and Phase C at 8s in the simulation time, the current of Phase B and Phase C increased and the voltage decreased which cause unhealthy state in the power network. In all, fault conditions cause unstable network condition which require urgent attention to avoid breakdown of the transmission line infrastructure.**

Keywords— Faults, Transmission Line, Power Network, Single Line-To-Ground Faults, Double Line-To-Ground Faults, Line-To-Line Faults

1. INTRODUCTION

The economic wellbeing of any nation is impacted by state of their nation power system [1,2]. Remarkably, the national power has been known to be the most economical means of power supply [3,4]. As such effective and reliable national power system is paramount for sustainable economic development of any nation. However, the ability to deliver power effectively through the power transmission networks is in some cases threatened by faults which cause abnormal phase voltages and phase currents distribution on the transmission lines; a situation that if not promptly checked can lead to more damages on the power system [5,6,7,8,9]. In view of this, fault detection and location mechanisms are employed to tackle the problems emanating from occurrence of faults on power transmission network [0,11,12,13,14,15].

In practice, there are several categories of faults that can occur on power transmission networks [16,17,18]. Each of the fault categories has some features that can be used to detect their occurrence and also some means to localise the location or area where such fault has occurred. Accordingly, in this paper, approach to detect some selected transmission line fault is presented. Notably, fault detection machismo is essential the power system operating status monitoring and initiation of measures to locate faulty areas and to isolate such area to avert further damages on the entire power system. Specifically, in this paper, three transmission line faults are analytically modelled and simulated using Simulink models and Matlab program. The three transmission line fault categories studied include; the single line to ground fault [19], the two-phase to ground fault [20] and the two-phase line-to-line fault [21]. The details of the analytical model, the Simulink model and the simulation results and discussion are presented for the three case study transmission line fault categories.

2. MODELLING OF THE FAULTS ON TRANSMISSION LINE NETWORK

In this section analytical models for determination of the phase current and phase voltages of the transmission line with incidence of fault are presented. Specifically, the faults considered include single line-to-ground fault, double line-to-ground fault and line-to-line fault.

2.1 SINGLE LINE-TO-GROUND FAULT

Consider a power transmission network with phase a shorted to ground at F, and in this fault situation, the currents in Phase b and c are negligible, hence; $I_b = I_c = 0$. Then, for the positive sequence current the following expressions apply [23];

$$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c) \quad (1)$$

$$I_{a1} = \frac{I_a}{3} \quad (2)$$

Also, for the negative sequence current the following expressions apply;

$$I_{a3} = \frac{1}{3}(I_a + a^2 I_b + a I_c) \quad (3)$$

$$I_{a2} = \frac{I_a}{3} \quad (4)$$

Again, for the zero-sequence current the following expressions apply;

$$I_{a0} = \frac{I_a}{3} \quad (5)$$

Then, for the single line-to-ground fault, the following expressions apply;

$$I_{a1} = I_{a2} = I_{a0} = \frac{I_a}{3} \quad (6)$$

$$E_1 = E_a \quad (7)$$

$$E_2 = 0 \quad (8)$$

$$E_0 = 0 \quad (9)$$

Let the sequence impedances with respect to the fault be denoted as Z_1, Z_2, Z_o, then for the sequence voltages, the following expressions apply;

$$V_{a1} = E_1 - I_{a1} Z_1 \quad (10)$$

$$V_{a2} = 0 - I_{a2} Z_2 \quad (11)$$

$$V_{a0} = 0 - I_{a0} Z_0 \quad (12)$$

Now, because phase a is shortened to the ground, then, $V_a = 0$. Also,

$$V_a = V_{a1} + V_{a2} + V_{a0} \quad (13)$$

Hence,

$$0 = E_1 - I_{a0}(Z_1 + Z_2 + Z_0) \quad (14)$$

This gives;

$$I_{a0} = \frac{E1}{Z_1 + Z_2 + Z_0} \quad (15)$$

Then, for the phase currents, the following expressions apply;

$$I_a = \frac{3Et}{Z_1 + Z_2 + Z_0} \quad (16)$$

$$I_b = 0 \quad (17)$$

$$I_c = 0 \quad (18)$$

Also, for the phase voltages, the following expressions apply;

$$V_a = 0 \quad (19)$$

$$V_b = E_b(1 - a)\left[\frac{Z_0 + (1+a)Z_2}{Z_1 + Z_2 + Z_0}\right] \quad (20)$$

$$V_c = E_c(1 - a)\left[\frac{(1+a)Z_0 + Z_2}{Z_1 + Z_2 + Z_0}\right] \quad (21)$$

2.2 DOUBLE LINE-TO-GROUND FAULT

In order to model the double line-to-ground fault in a transmission line network, we consider the situation where phase b has fault impedance denoted as Zf, phase c fault impedance is denoted as Z_f; and Z_g is used to define the common line-to-ground fault impedance. Then, the boundary conditions are expressed as follows [23];

$$I_a = 0 \quad (22)$$

$$V_{bn} = I_b(Z_f + Z_g) + I_c Z_g \quad (23)$$

$$V_{cn} = I_b Z_g + (Z_f + Z_g) I_c \quad (24)$$

The phase b and phase c potential difference is expressed as follows:

$$V_{bn} - V_{cn} = I_b Z_f - I_c Z_f \quad (25)$$

Hence,

$$(a^2 - a)(V_{a1} - V_{a2}) = (a^2 - a)(I_{a1} - I_{a2}) Z_f \quad (26)$$

$$V_{a1} - I_{a1} Z_f = V_{a2} - I_{a2} Z_f \quad (27)$$

$$V_{bn} + V_{cn} = (I_b + I_c)(Z_f + 2Z_g) \quad (28)$$

With respect to the sequence quantities we have

$$2V_{a0} - V_{a1} - V_{a2} = (2I_{a0} - I_{a1} - I_{a2})(Z_f + 2Z_g) \quad (29)$$

Then, since $I_a = 0$, we obtain

$$I_{a1} + I_{a2} + I_{a0} = 0 \quad (30)$$

$$2V_{a0} - 2V_{a1} - 2V_{a2} = 3I_{a0}(Z_f = 2Z_g) \quad (31)$$

$$V_{a0} - I_{a0}(Z_f + 3Z_g) = V_{a1} - I_{a1} Z_f \quad (32)$$

Notably,

$$V_{a1} = E_1 - I_{a1} Z_1 \quad (33)$$

$$V_{a2} = I_{a2} Z_2 \quad (34)$$

$$V_{a0} = I_{a0} Z_0 \quad (35)$$

Then;

$$E_1 - I_{a1}(Z_1 + Z_f) = -I_{a2}(Z_2 - Z_f) = -I_{a0}(Z_0 + Z_f + 3Z_g) \quad (36)$$

$$I_{a1} = \frac{E_1}{Z_1 + Z_f \frac{(Z_2 + Z_f)(Z_0 + Z_f + 3Z_S)}{Z_2 + Z_0 + 2Z_f + 3Z_g}} \quad (37)$$

For the negative sequence current the following expressions apply;

$$I_{a2} = I_{a1}\left[\frac{Z_0 + Z_f + 3Z_g}{Z_2 + Z_0 + 2Z_f + 3Z_g}\right] \quad (38)$$

$$I_{a2} = -(I_{a1} + I_{a2}) \quad (39)$$

2.3 LINE-TO-LINE FAULT

In order to model the line-to-line fault in a transmission line network, we consider the situation where a short circuit occurs between two phases. In this case we consider three-phase system where there is a line-to-line short circuit that occurred between phase b and phase c. Then, the boundary conditions are expressed as follows [23];

$$I_a = 0 \quad (40)$$

$$I_b = -I_c \quad (41)$$

$$V_{bc} = I_b Z_f \quad (42)$$

Solving the first two conditions gives;

$$I_{a0} = 0 \quad (43)$$

$$I_{a1} = -I_{a2} = \frac{1}{3}(a - a^2)I_b \quad (44)$$

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^0}{Z_1 + Z_2 + Z_f} \quad (45)$$

Solving for the voltage conditions we obtain;

$$(a^2 - a)(V_{a1} - V_{a2}) = Z_f(a^2 - a)I_{a1} \quad (46)$$

Hence;

$$V_{a1} - V_{a2} = Z_f I_{a1} \quad (47)$$

$$V_{a1} = 0 \quad (48)$$

$$V_{a1} = 1.0 - Z_1 I_{a1} \quad (49)$$

$$V_{a2} = -Z_2 I_{a2} = Z_2 I_{a1} \quad (50)$$

2.4 SIMULINK MODELS FOR THE FAULT ON TRANSMISSION LINE NETWORK

Simulink models are developed for the simulation of fault detection on a 330kV transmission line

Network based on the three different fault categories considered in the study. Specifically, the single line to ground fault Simulink model is presented in Figure 1, the two-phase to ground fault Simulink model is presented in Figure 2 and the two-phase (Phase A and B) line-to-line fault Simulink model is presented in Figure 3.

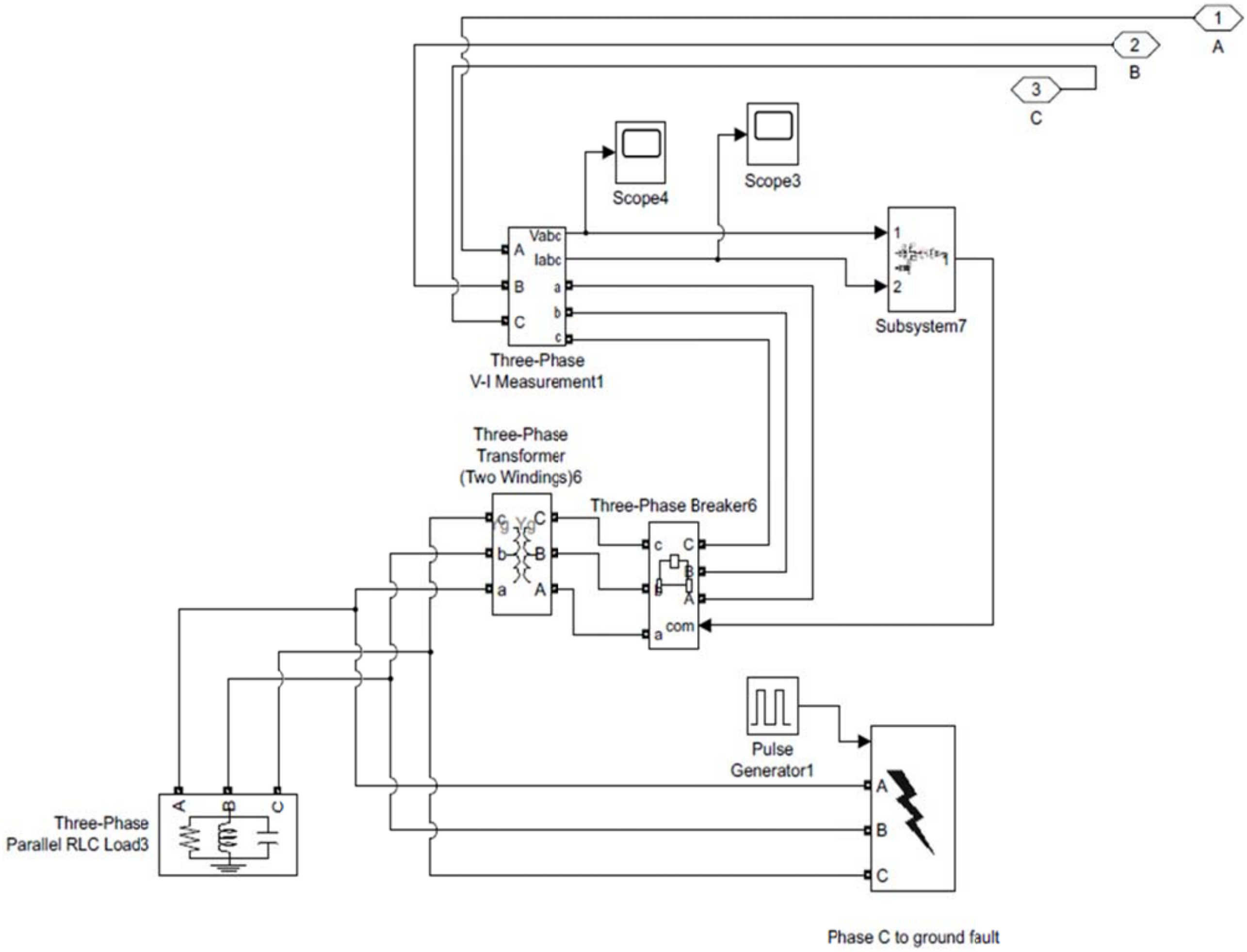

Figure 1 Single Line to Ground Fault

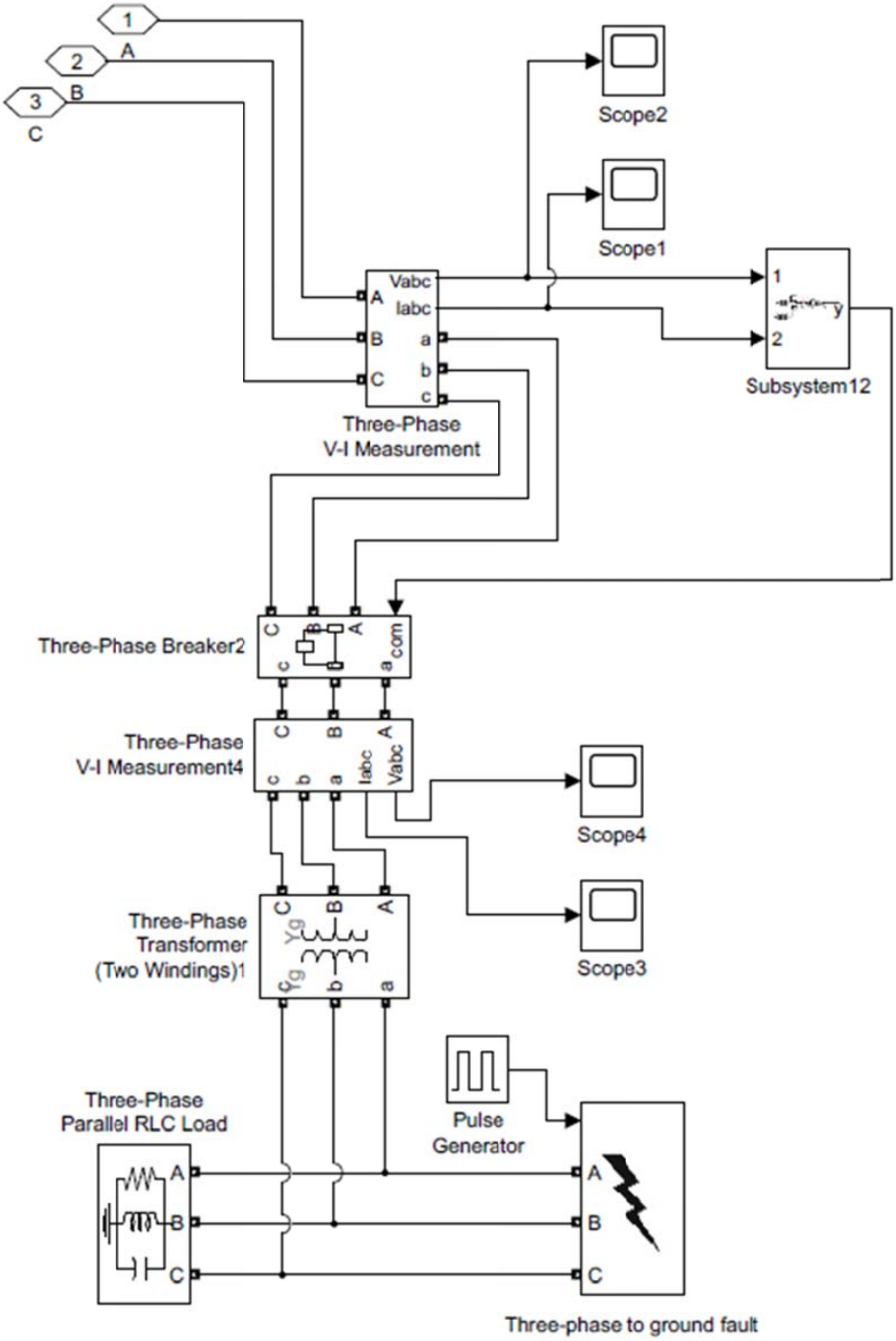

Figure 2 Two-Phase to Ground Fault

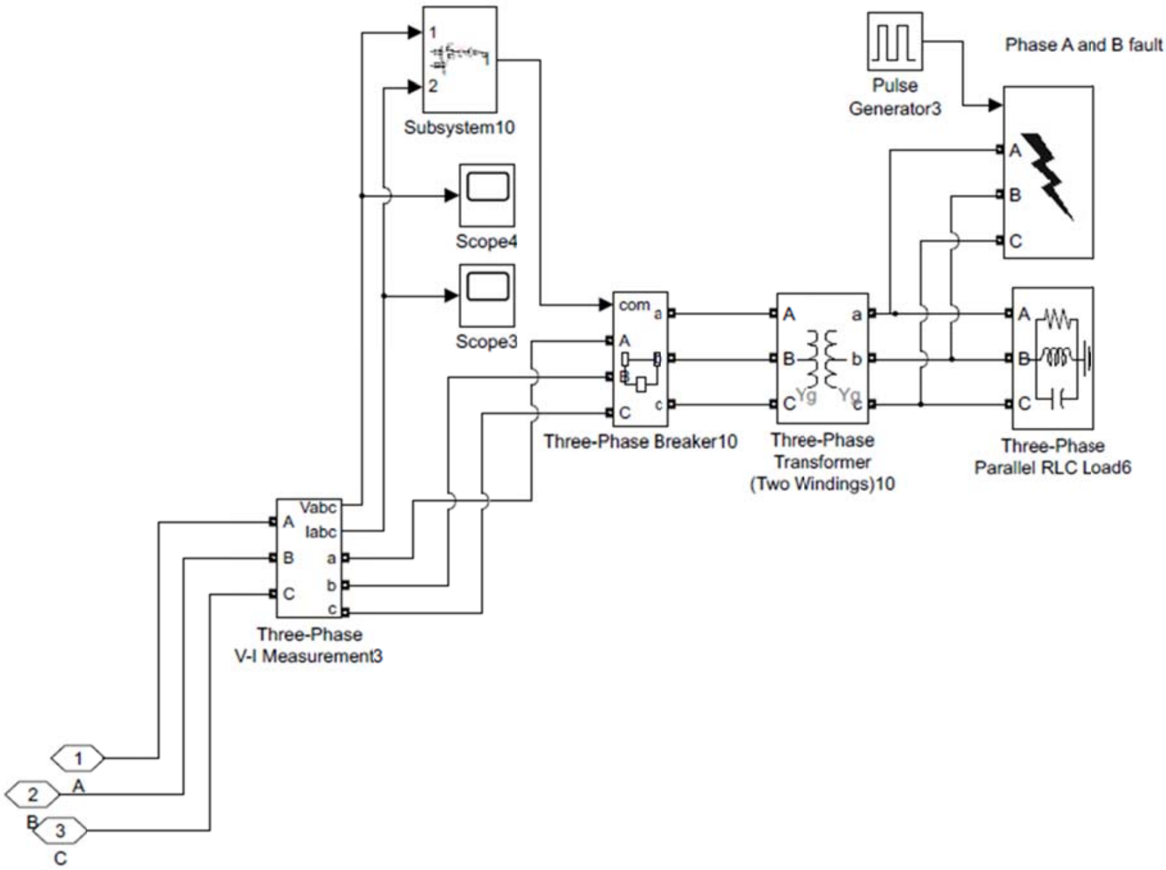

Figure 3 Two-Phase (Phase A and B) Line-to-Line Fault

3. RESULTS AND DISCUSSION

The three different fault categories were simulated in matlab. The three fault categories modelled and simulated are the single line to ground fault, the two-phase to ground fault and the two-phase (phase A and B) line-to-line fault.

3.1 RESULTS FOR THE SINGLE LINE TO GROUND FAULT

Simulation of the single line to ground fault was carried out using a simulated three-phase fault block in Simulink shown in Figure 1 and the results obtained for the current and voltage reading obtained for the single line to ground fault are presented in Figure 4 and Figure 5 respectively. A pulse block in Simulink was used to simulate switching on the single line to ground fault from 4 seconds of simulation time. In this case, the fault was applied to Phase C or line 3, as shown in the Simulink model in Figure 1. Specifically, the fault was introduced at the 4th second (that is time =4 s) as shown in the results presented in Figure 4 and Figure 5. Before the fault was introduced (that is before 4s) the waveform of the current and voltage were stable but when the fault was introduced to Phase C or line 3 at 4s the current of Phase C or line 3 increased and the voltage decreased which cause unhealthy state in the power network, as shown in Figure 4 and Figure 5.

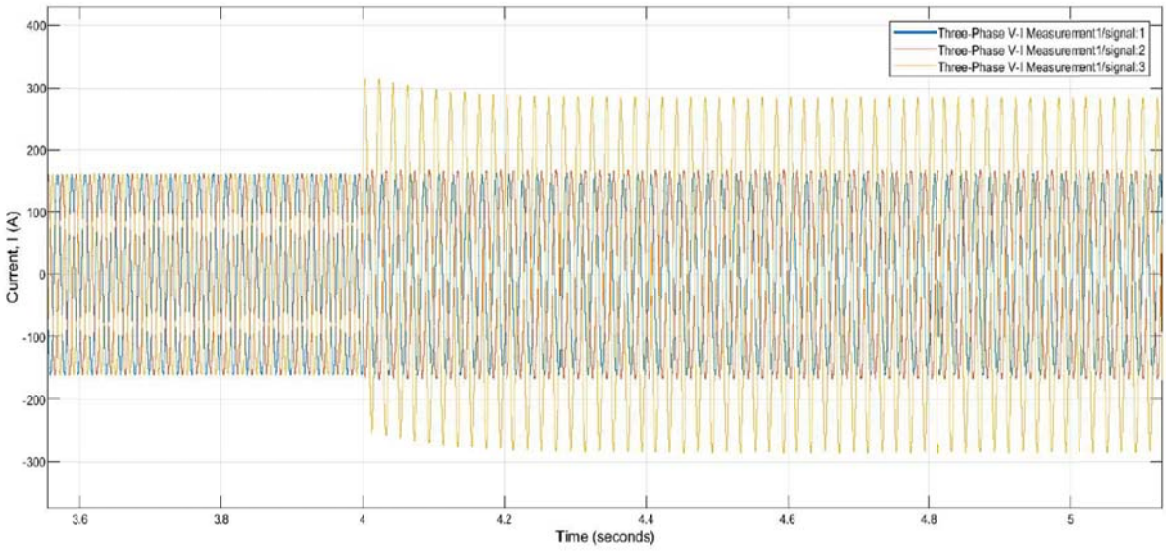

Figure 4: Current Variations with Time in a Single Line to Ground Fault Simulation

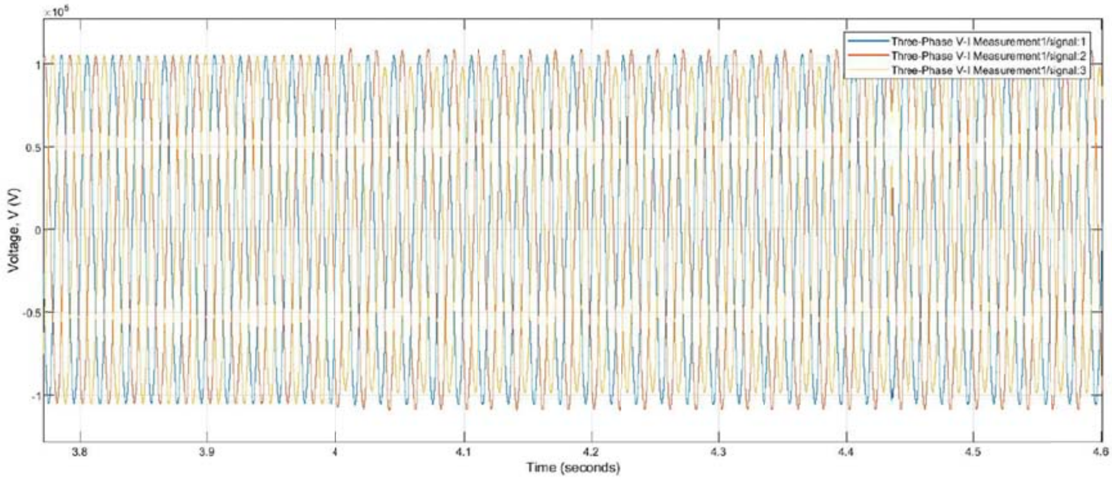

Figure 5: Voltage Variations with Time in a Single Line to Ground Fault Simulation

3.2 RESULTS FOR THE TWO-PHASE TO GROUND FAULT

Two-phase to ground fault (with Simulink model shown in Figure 2) was simulated for a double line to ground fault involving phases B and C. The fault was introduced eight (6) seconds into the simulation time. The resultant variation in current and voltage are shown in Figures 6 and Figure 7.

Before the fault was introduced (that is before 6 s in the simulation time) the waveform of the current and voltage were stable but when the fault was introduced to Phase B and Phase C at 8s the current of Phase B and Phase C increased and the voltage decreased which cause unhealthy state in the power network, as shown in Figure 6 and Figure 7.

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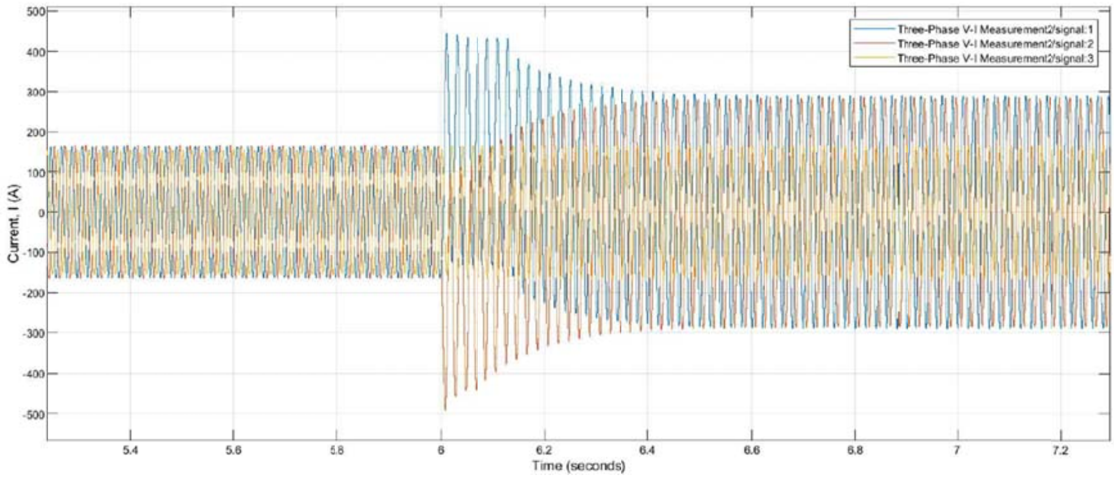

Figure 6: Variations in Current in a Two-Phase to Ground Fault Simulation

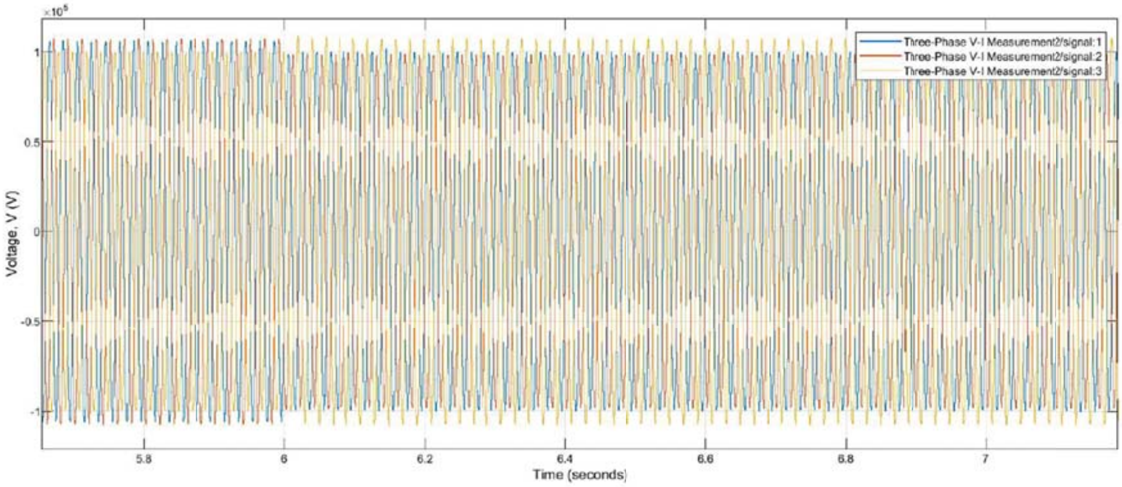

Figure 7: Variations in Voltage in a Two-Phase to Ground Fault Simulation

3.3 RESULTS FOR THE TWO-PHASE (PHASE A AND B) LINE-TO-LINE FAULT

Two-phase fault (with Simulink model shown in Figure 3) was simulated between phases A and B. The fault was introduced at eight (8) seconds into the simulation time, as shown in the resultant variation in current and voltage of Figure 8 and Figure 9 respectively. Before the fault was introduced (that is before 8 s in the simulation time) the waveform of the current and voltage were stable but when the fault was introduced to Phase A and Phase B at 8s the current of Phase A and Phase B increased and the voltage decreased which cause unhealthy state in the power network, as shown in Figure 8 and Figure 9 respectively.

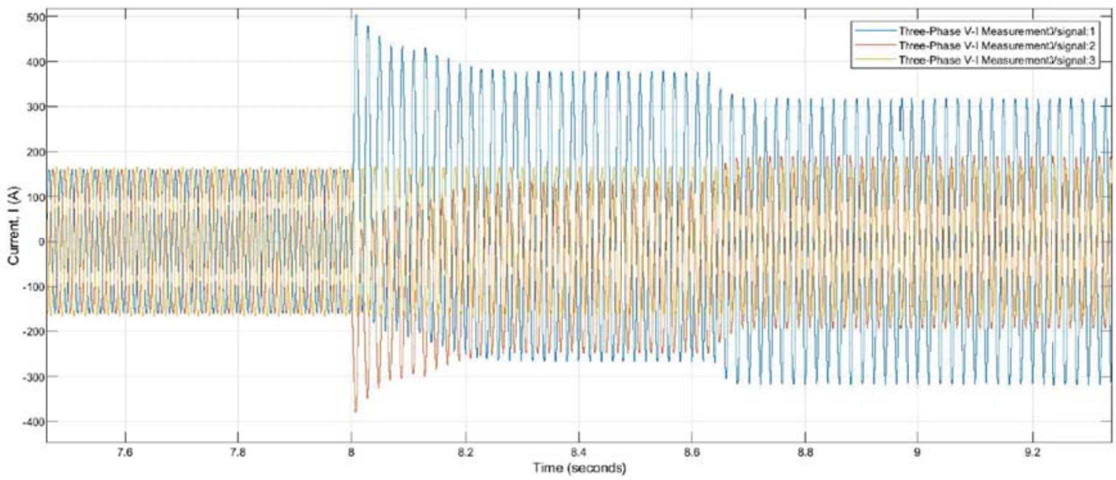

Figure 8: Variations in Current with Time in a Two-Phase Fault Simulation

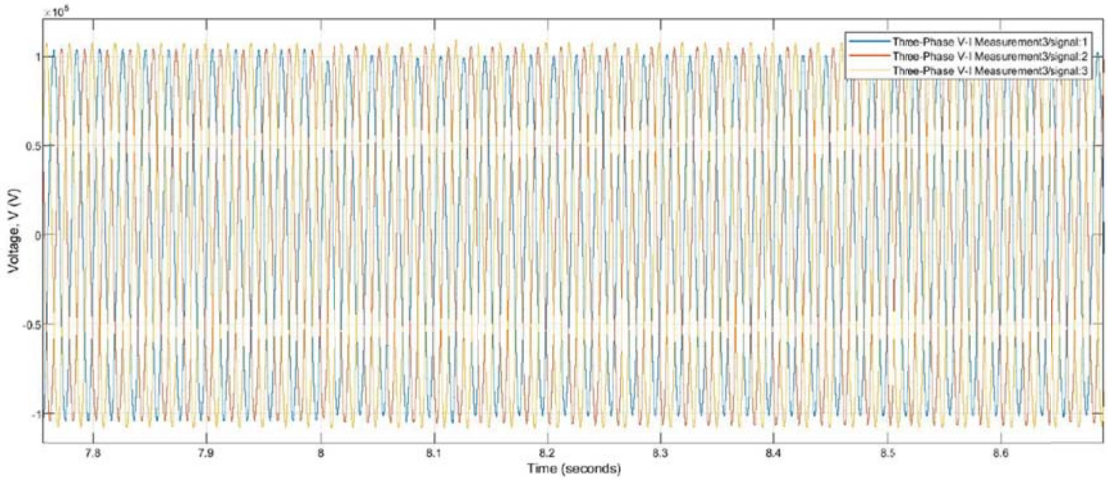

Figure 9: Variations in Voltage with Time in a Two-Phase Fault Simulation

4.0 CONCLUSION

In this paper, modelling and evaluation of faults on a 330 KV transmission line network is presented. Analytical models and Simulink models are presented for the simulation and evaluation of fault detection on the case study 330kV transmission line.

Among the various fault categories, in this paper three faults were considered, namely; the single line to ground fault, the two-phase to ground fault and the two-phase line-to-line fault. The models for the faults were simulated in Matlab and the results show the variations in the phase current and voltage for the transmission lines. In all, the results showed that the occurrence of fault causes the current to increase and the voltage to decrease in some of the affected phases.

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