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ANALYSIS AND EVALUATION OF FAULTS ON A 330 KV TRANSMISSION LINE NETWORK IN SOUTHERN NIGERIA FOR IMPROVE PERFORMANCE

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ABSTRACT

The analysis of transmission lines under fault condition represents one of the most important and complex task in Power Engineering. The studies and detection of these faults is necessary to ensure that the reliability and stability of the power system do not suffer a decrement as a result of a critical event such a fault. This project conduct a research, analyse and evaluate the behaviour of a transmission lines under fault conditions and evaluate different scenarios of faults. This was done using ETAP 16. Fault is an abnormal condition that involves an electrical failure of power system equipment operating at one of primary voltage within the system**.** It was revealed that three-phase fault, the voltages at faulted buses phases dropped to zero, voltage at Phase A is equal to zero in single line-to-ground fault double line-to-ground fault, Phase B and C voltages are equal to zero and this type of fault is the most sever fault on the system. Positive sequence bus 1, has the lowest resistance of 2.80435 Ω and impedance of 12.003 Ω, bus 57 has the highest resistance of 63.5967 Ω, with the highest reactance of 59.4 Ω in bus 57 and bus 2 has the lowest reactance of 11.296 Ω and the highest impedance of 86.99 in bus 57. Negative sequence, bus 1 has the lowest resistance of 3.24 Ω, lowest reactance of 11.161 Ω and lowest impedance of 11.622 and bus 57 has the highest resistance of 63.95 Ω, highest reactance and impedance of 57.4 Ω and 85.92 Ω respectively.

For zero sequence impedance, the lowest resistance is in bus 1 with the value of 1.076 Ω, the lowest reactance of 3.41 Ω and the lowest impedance of 3.541 Ω. The highest resistance is bus 3 with the values of 117.65 Ω, the highest reactance is bus 57 with the value of 85.89 Ω and the highest impedance in bus 3 with the value of 122.16 Ω.

Key Words; Faulty Lines, Evaluation, Transmission network, Fault Sequences, Fault Phase.

1.0 INTRODUCTION

Electrical power is generated from power plants which there are differs sources. The energy is transmit from the generating points through a lines which is the transmission to the distribution of which the users are tapped into it. There are voltages difference from the generation to the consumer points. This voltage level depends on the usage.[1]The change in the voltage level is done with the help of a transformer, and high voltage transmission help reduces losses on the line. [2] The main aim of all power systems is to ensure the continuity in power flow. But lightning and other natural occurrences such as wind, ice, equipment failure, and other untimely events may cause a fault between the phase's wires of the transmission line and to ground [4]. This fault currents are caused by short circuits on the lines can be determined by the impedance of the system between the fault and generator voltages, which may be higher in magnitude than the normal operating currents. Thus, fault persistence, may results to damage of the equipment and lead to long-term power loss. For prevention purpose of such accident, one should disconnect the faulted part from the entire system temporarily as soon as possible.[3] the occurrence of fault in power systems result in losing the system stability and cause damages in faulted equipment or close healthy devices.[5,7,9] stability modelling is responsible as an important component in energy management, planning and optimization of power systems network [10] the system will draws a large current at a starting period, which causes a voltage drop of system and set a disturbances to the uniform operation of other loads. A transient fault, by instantly tripping of one or several circuit breakers in order isolate the fault, faults are cleared and which does not recur when the line is re-energized.[14] Lightning is one of the most common cause of transient faults, which is as a result of insulator flashover that is from the high transient voltages induced by this lightning. Others such as swinging wires and non-constant contact with foreign objects. The transient faults can be cleared by instant of de-energizing the line, which will allow the fault to clear. [15, 16, 17, 18]

2.0 MODELLING Single Line –to- Ground Faults

Assume that the phase a is shorted to ground at the fault point F, Phase b and c currents are assumed to be negligible, we write $I_b = 1_c = 0$

Obtained sequence currents as follows:

Positive sequence value we use

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

This gives

$I_{a1} = \frac{1_a}{3}$ (2)

The negative sequence current

$I_{a3} = \frac{1}{3}(1_a + a^2 I_b + aI_c)$ (3)

This gives

$I_{a2} = \frac{1_a}{3}$ (4)

Likewise for the zero sequence current we get

$I_{a0} = \frac{1_a}{3}$ (5)

We conclude that for a single line-to-ground fault, the sequence currents are equal, thus

$I_{a1} = I_{a2} = I_{a0} = \frac{1_a}{3}$ (6)

Producing balanced three phase voltages from generator, which are positive sequence only, we can write

$E_1 = E_a$

$E_2 = 0$

$E_0 = 0$

Assume sequence impedances to the fault are given by Z_1, Z_2, Z_o.

The expressions for sequence voltages as the fault:

$V_{a1} = E_1 - I_{a1}Z_1$ (7)

$V_{a2} = 0 - I_{a2}Z_2$ (8)

$V_{a0} = 0 - I_{a0}Z_0$ (9)

The fact that phase a is shortened to the ground is used. Thus $V_a = 0$

We also recall that

$V_a = V_{a1} + V_{a2} + V_{a0}$ (10)

We conclude

$0 = E_1 - I_{a0}(Z_1 + Z_2 + Z_0)$ (11)

Or

$I_{a0} = \frac{E1}{Z_1+Z_2+Z_0}$

We can now state that solution in terms of phase currents:

$I_a = \frac{3Et}{Z_1+Z_2+Z_0}$ (13)

$I_b = 0$

$I_c = 0$

For phase voltages we have

$V_a = 0$

$V_b = E_b(1-a)\left[\frac{Z_0+(1+a)Z_2}{Z_1+Z_2+Z_0}\right]$ (14)

$V_c = E_c(1-a)\left[\frac{(1=a)Z_0+Z_2}{Z_1+Z_2+Z_0}\right]$ (15)

The last two expressions can be derived easily from the basic relations.

For phase b, we have

$V_b = a^2 V_{b1} + aV_{b2} + V_{b0}$ (16)

Using equations 3.7, 3.8, and 3.9, we find that

$V_b = a^2(E_1 - I_{b1}Z_1) + A(0 - I_{b2}Z_2) + a(0 - I_{b0}Z_0)$

Which reduces to

$V_b = \frac{E_1(a^2-a)Z_2+(a^2-1)Z_0}{Z_1+Z_2+Z_0}$ (19)

And since

$E_b = a^2 E_1$ (20)

We obtain

$V_b = E_b(1-a)\left[\frac{Z_0+(1+a)Z_2}{Z_0+Z_2+Z_2}\right]$ (21)

Similarly, we get the result for phase c.

2.1 Double Line-to-Ground Faults

In this case, we will consider a general fault condition. We assume that phase b has fault impedance of Z_f, phase c has a fault impedance of Z_f; and the common line-to-ground fault impedance is Z_g

The boundary conditions are as follows:

$I_a = 0$

$$V_{bn} = I_b(Z_f + Z_g) + I_c Z_g \quad (22)$$

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

The potential difference between phase b and c is thus

$$V_{bn} - V_{cn} = I_b Z_f - I_c Z_f \quad (24)$$

Substituting in terms of sequence currents and voltages, we have

$$(a^2 - a)(V_{a1} - V_{a2}) = (a^2 - a)(I_{a1} - I_{a2})Z_f \quad (25)$$

As a result, we get

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

The sum of the phase voltages is

$$V_{bn} + V_{cn} = (I_b + I_c)(Z_f + 2Z_g) \quad (27)$$

In terms of sequence quantities this gives

$$2V_{a0} - V_{a1} - V_{a2} = (2I_{a0} - I_{a1} - I_{a2})(Z_f + 2Z_g) \quad (28)$$

Recall that since $I_a = 0$, we have

$$I_{a1} + I_{a2} + I_{a0} = 0 \quad (29)$$

We can thus assert that

$$2V_{a0} - 2V_{a1} - 2V_{a2} = 3I_{a0}(Z_f = 2Z_g) \quad (30)$$

Substituting for V_{a0} from the equation 3.26, we get

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

The above reduces to

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

Now we have

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

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

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

Consequently,

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

It is clear from equation (3.36) that the sequence networks are connected in parallel,

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

The negative sequence current in

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

Finally,

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

2.3 Line-to-Line Faults

For line-to-line fault a short circuit occurs between two phases, three-phase system with a line-to-line short circuit between phases b and c. the boundary conditions are

$I_a = 0$

$$I_b = -I_c \quad (40)$$

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

The first two conditions yield

$I_{a0} = 0$

$$I_{a1} = -I_{a2} = \frac{1}{3}(a - a^2)I_b \quad (43)$$

Or

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^0}{Z_1 + Z_2 + Z_f} \quad (44)$$

The voltage conditions give

$$(a^2 - a)(V_{a1} - V_{a2}) = Z_f(a^2 - a)I_{a1} \quad (45)$$

Which gives

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

Or

$V_{a1} = 0$

$$V_{a1} = 1.0 - Z_1 I_{a1} \quad (47)$$

$$V_{a2} = -Z_2 I_{a2} = Z_2 I_{a1} \quad (48)$$

The equivalent circuit will take on the form shown in figure 3.6. Note that the zero sequence network is not included since $I_{a0} = 0$.

2.4 Balanced Three-Phase fault

Let us now consider the situation with a balanced three-phase fault on phases a, b, and c, all through the same fault impedance Z_f. this fault condition. it is clear from inspection of this figure that the phase voltages at the fault are represented by

$$V_a = I_a Z_f \quad (49)$$
$$V_b = I_b Z_f \quad (50)$$
$$V_c = I_c Z_f \quad (51)$$

The positive sequence voltages are obtained using the following

$$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2 V_c) \quad (52)$$

Using equations (49; 50 and 51), it was concluded that

$$V_{a1} = \frac{1}{3}(1_a + aI_b + a^2 I_c)Z_f \quad (53)$$

However, for currents we get

$$V_{a1} = I_{a1} Z_f \quad (54)$$

The negative sequence voltage is similarly given by

$$V_{a2} = I_{a2} Z_f \quad (55)$$

The zero sequence voltage is also

$$V_{a0} = I_{a0} Z_f \quad (56)$$

For a balanced source we have

$$V_{aq} = E - I_{a1} Z_1 \quad (57)$$
$$V_{a2} = 0 - I_{a2} Z_2 \quad (58)$$
$$V_{a0} = 0 - I_{a0} Z_0 \quad (59)$$

Combining equations (3.54 and 3.57), it was to conclude

$$V_{a1} = E - I_{a1} Z_1 = I_{a1} Z_f \quad (60)$$

As a result,

$$I_{a1} = \frac{E}{Z_1 + Z_f} \quad (61)$$

Combining equations (3.55 and 3.58) gives

$$I_{a2} = 0$$

Finally equations (3.56 and 3.59) give

$$I_{a0} = 0$$

3.0 RESULT PRESENTATION

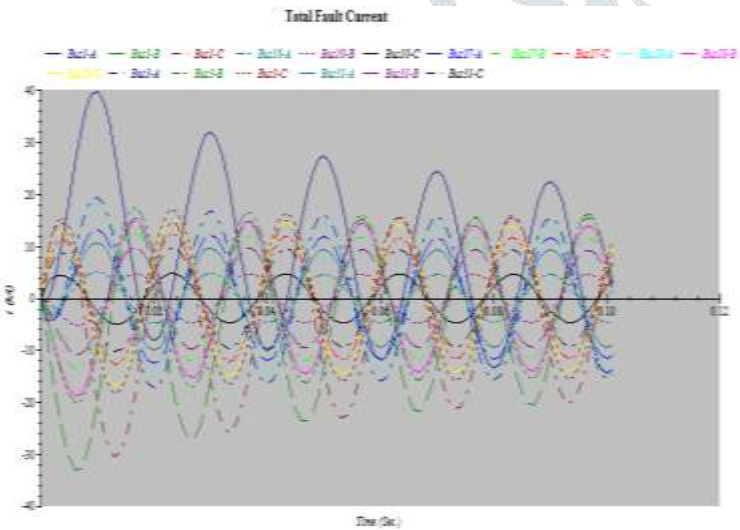

Fig.1: Graph of current (A) against time (sec) for bus 1, 3,10, 27, 28 and 31

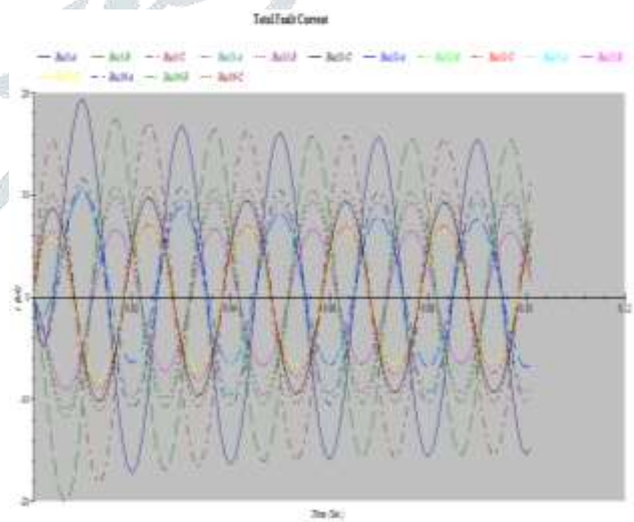

Fig.2: Graph of current (A) against time (sec) for bus 3, 31, 32,35 and 36

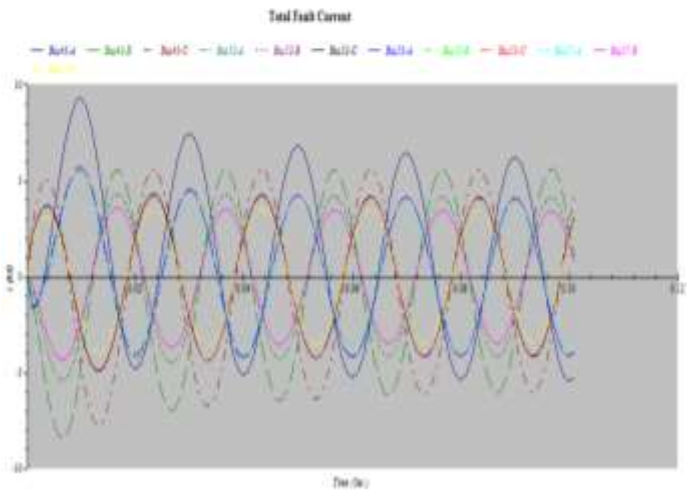

Fig.3: Graph of current (A) against time (sec) for bus 36, 37, 38, and 43

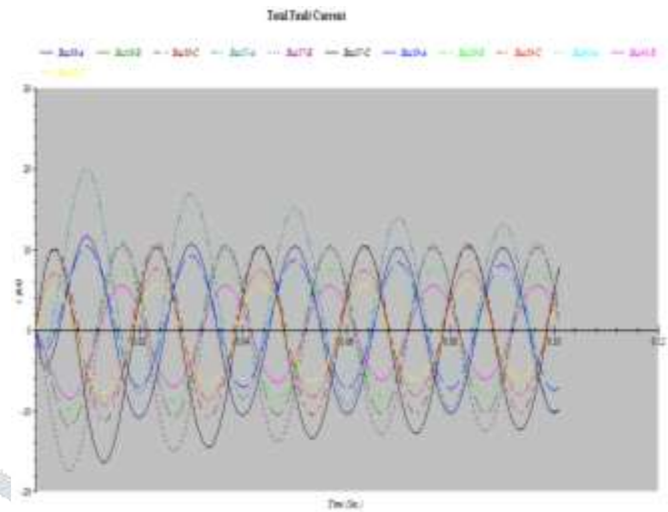

Fig.4: Graph of current (A) against time (sec) for bus 43, 52, 53, and 57

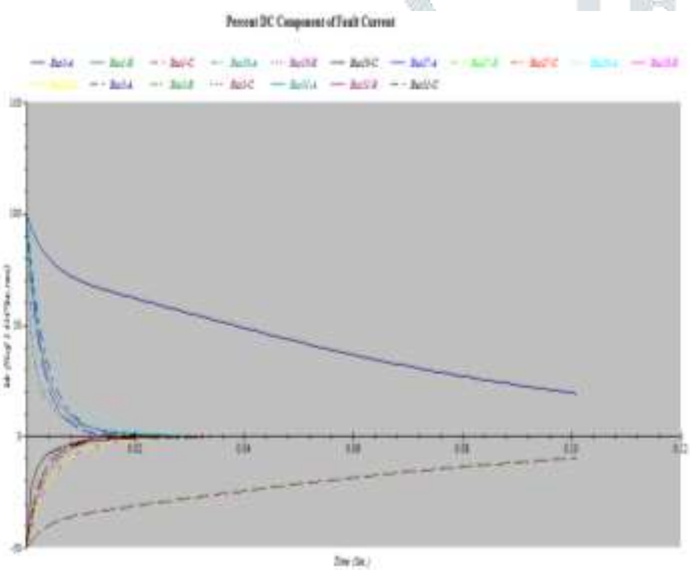

Fig.5: Graph of current (A) against time (sec)

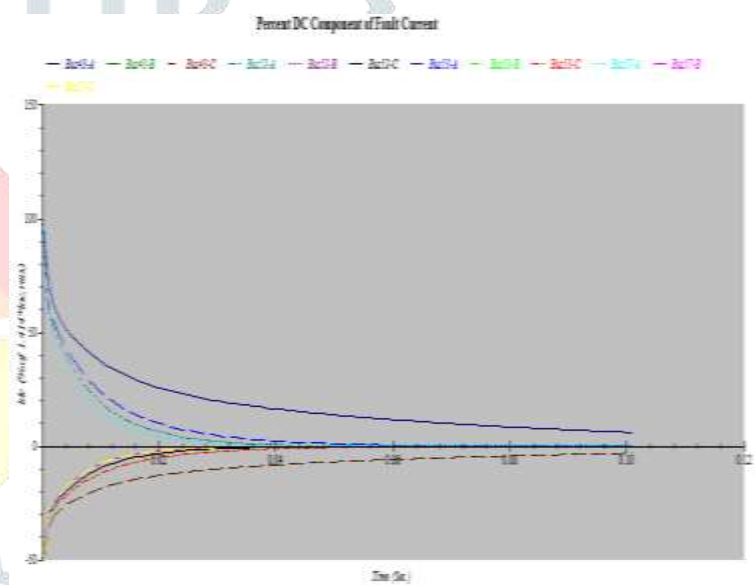

Fig.6: Graph of current (A) against Time (sec)

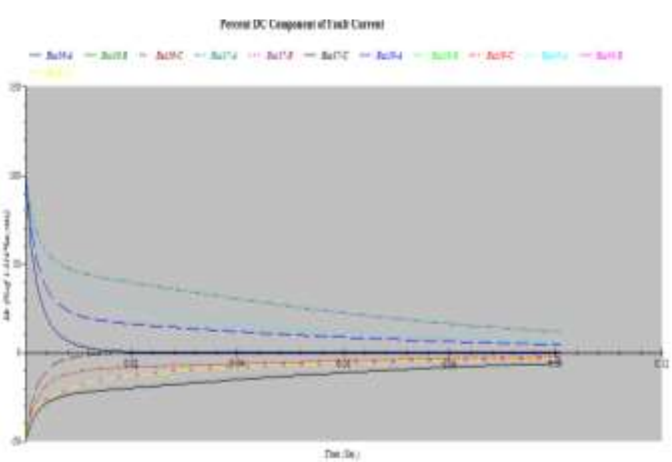

Fig.4.8: Graph of current (A) against Time (sec)

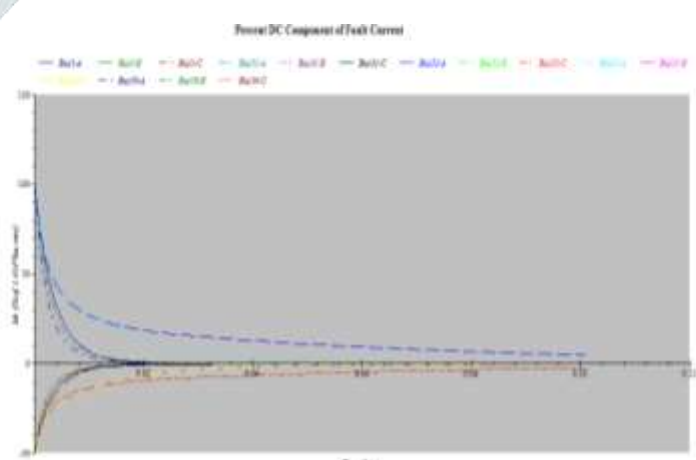

Fig.4.9: Graph of current (A) against Time (sec)

4.0 Result Discussion

The network consist of 27 buses and 15 buses were faulted, the simulation results shows the line to line faults, line to ground faults and line to line to ground faults. The summary of the simulations shows the three phase faults currents which includes sub-transient, transient and steady state currents as shown the table below

Table 1.0. 3 phase faults current

Short-Circuit Summary Report

3-Phase Fault Currents

Bus ID	Bus kV	Short Circuit Current (kA, rms) Subtransient	Transient	Steady State
Bus1	330.000	18.378	13.183	7.183
Bus3	330.000	13.680	11.071	6.874
Bus10	330.000	3.554	3.283	3.219
Bus27	330.000	9.399	8.237	6.338
Bus28	330.000	12.259	9.991	6.732
Bus31	330.000	7.409	6.586	5.885
Bus32	330.000	6.140	5.163	4.202
Bus35	330.000	5.629	4.608	3.593
Bus36	330.000	8.202	7.295	5.958
Bus37	330.000	10.452	8.318	6.097
Bus39	330.000	6.363	5.532	4.948
Bus43	330.000	5.113	4.171	3.247
Bus52	330.000	3.455	2.958	2.497
Bus53	330.000	3.463	2.928	2.442
Bus57	330.000	2.810	2.457	2.167

It is seen that at sub-transient an transient the currents are high due to the existing of the faults but the steady state happen after the system has manage to overcome the faults at a particular time intervals..

For line to ground faults, bus 1, V_a is zero in magnitude and angle. Thus prove the formulations of the mathematical modelling of the faults type.

For line to line faults, bus 1, has currents of zero for both magnitude and angle at I_a. For line to line to ground faults V_b, V_c and Ia are zero for both magnitude and angles. In all the simulation results 3 phase faults has the highest magnitude, thus reveal the effects of three phase faults on the network.

Table 1.0, the table of summary of sequence impedance of the faulted buses. These sequence impedance include the following (a). Positive sequence impedance (b) Negative sequence impedance and (c.) Zero sequence impedance.

For positive sequence impedance, bus 1, has the lowest resistance of 2.80435 Ω and bus 57 has the highest resistance of 63.5967 Ω, with the highest reactance of 59.4 Ω in bus 57 and bud 2 has the lowest reactance of 11.296 Ω. But bus 1 with the lowest impedance of 12.003 Ω and the highest impedance of 86.99 in bus 57.

For negative sequence, bus 1 has the lowest resistance of 3.24 Ω, lowest reactance of 11.161 Ω and lowest impedance of 11.622 and bus 57 has the highest resistance of 63.95 Ω, highest reactance and impedance of 57.4 Ω and 85.92 Ω respectively.

For zero sequence impedance, the lowest resistance is in bus 1 with the value of 1.076 Ω, the lowest reactance of 3.41 Ω and the lowest impedance of 3.541 Ω. The highest resistance is bus 3 with the values of 117.65 Ω, the highest reactance is bus 57 with the value of 85.89 Ω and the highest impedance in bus 3 with the value of 122.16 Ω.

Fig.1, the amplitude of the total faults current was occurred at the time 0.01sec with the value of 39.8 amp with the smallest trough of -2amp at time 0.005sec.

Fig. 2 have the highest amplitude of 19.85amp at time 0.01sec at bus 3A and the smallest amplitude of 5.75amp at time 0.04sec at bus 35C. the highest trough of -20 amp at the time 0.01sec at bus 36B, smallest trough of 2.0amp at time 0.002sec at bus 35A.

Fig. 3 have the highest amplitude of 20.0 amp at time 0.008sec at bus 36b and the smallest amplitude of 5.0 amp at time 0.04sec at bus 43C. The highest trough of -20 amp at the time 0.01sec at bus 43A, smallest trough of -2.0amp at time 0.001sec at bus 43A

Fig. 4. Have the highest amplitude of 9.0 amp at time 0.012sec at bus 43C and the smallest amplitude of 6.0 amp at time 0.004sec at bus 57C. The highest trough of -8.5 amp at the time 0.008sec at bus 43B, smallest trough of -1.5.0amp at time 0.001sec at bus 53A

5.0 CONCLUSION

Fault analysis was done for a 27-bus system where 15 buses was faulted and the report of the faults LL, LG,and LLG

1 three-phase fault, the voltages at faulted buses phases reduces to zero during fault. The faulted buses are Phase A, Phase B and Phase C has a zero voltage potential.

2 moreover only voltage at Phase A is zero for single line-to-ground fault. In addition, only Phase A has current since it is the faulted phase in this type of fault as we assumed earlier in the mathematical model. This current is the second highest fault currents of all types.

3 Since Phase B and Phase C are in contact in line-to-line fault, the voltages at both phases are equal. The fault current are passing from B to C. in Phase A, the current is equal to zero compared to the fault current.

4 In double line-to-ground fault, Phase B and C voltages are equal to zero. The faulted current is flowing through both phases only. In addition, this type of fault is the most sever fault on the system which can be seen from its current value.

This work is strongly recommended to the power system planning, management and optimization engineers to absorbed this work and acts fast in order to reduce losses both in capital expenses and energy users. The cost of transmission and protection of the network will also reduce. This is so because high energy losses result to high tariff and when there is a lower losses on the network, the reliability of the network will be improved, stability is attained and optimum dispatch on the network is guarantee. The transmission company of Nigeria should do something about the losses in order to reduce it. This could be done by involving of professionals, technical teams of engineers in the field of power system and some technical government officials since transmission is manage by the government.

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