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Electric Power Faults Evaluation On 33KV Distribution Network

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Abstract-* Electric fault occurs as a result of insulation breakdown in either generation, transmission or distribution system, power systems at various stages experience distinct level of instability which amounts to system unreliability. This research is focused on evaluating electric power faults with the aim of determining its type and effect on the people of Beneku, Abragada and Abor communities in Niger Delta. The 33kV distribution networks in each of the afore-stated communities were duly investigated and classification was based on collated network parameters and fault occurrence. The proceed of the evaluation justified and validated the fact that single line to ground fault (SLGF) is the most prevalent and three phase balanced fault is least prevalent in power systems analysis. The numerical method of Newton-Raphson was used to determine the fault currents and line impedances of the respective feeders based on phases, while electrical transient analyzer program (ETAP) simulation software was used to implement all the analysis conducted. The magnitude of the fault current for SLGF on phase A for Beneku, Abragada and Abor communities were found be $0.452\angle-77.3°kA$, $0.380\angle-76.2°kA$ and $0.482\angle-77.8°kA$ with zero line impedances. Upon successful evaluation and classification, it was observed that the people of Beneku, Abragada and Abor communities suffer long and frequent power outage as a result of time lag in fault location identification. As a way of curbing this menace, the low resistance method of fault location identifier technique was suggested due to its cost effectiveness to enable electrical engineers tackle fault problem as quick as possible.

***Indexed Terms-* Electrical Transient Analyzer Program (ETAP) Software, single line to ground fault, line impedances, power outage.**

I. INTRODUCTION

The consistency quality of electricity delivered to consumer has become an important factor that affects the drive needed for technological growth and development of modern facilitate in the society. According to [1] fault occurrence in our power system causes operational breakdown and also cause failure in industrial and household equipment. In the perspective of [2] this fault are subdivided into transient and permanent faults. In the view of [3] transient fault allows the circuit to be safely re-energized after a short period and do not damage the insulation permanently. According to [4] transient over voltages in power systems may be caused due to several reasons such has lightning strikes or operations switching of inductive or capacitive system which are the commonest.

The frequent occurrences of faults on any distribution networks are single phase-to-earth (LG) fault; double phase-to-earth (LLG) fault, phase-to-phase (LL) fault and three phase-to-earths (LLLG) fault, which the single line to earth fault is the most common fault type and it occurs most frequently [5]. In the view of [6], the most widespread faults in the distribution networks 6–35 kV are single line-to-earth faults (SLEF), which account for approximately, 60–80% of total number of faults. Electricity companies' consumer investigation shows that the distribution system account for maximum unavailability power supply to customer's due to faults [7]. In the perspective of [8], over 90% of electricity distribution customer account for fault problems.

This research work identify fault that influences electrical power performance in 33KV distribution feeder to Beneku, Abragada and Abor community in Delta State, Nigeria. During this research, the condition of all relevant equipment for power distribution in the aforementioned communities was assessed for load flow analysis. The determination of Fault Current and Line Impedance using Newton-Raphson method for fault analysis was considered.

ETAP simulation software was used in simulating the 33kV distribution network connected to communities.

II. LITERATURE REVIEW

Electric energy is produced by large generating stations with the application of different technology, such as: coal, hydro, nuclear or natural gas which is located far from the load points [9]. The transmission system consists of line conductors and other power system equipment's, these line conductors operate at high voltages of 330KV and 132KV and transmit bulk electric power over longer distances overhead system [10]. In the view of [11], the sub transmission system is linked or intermediary system that connects the transmission and distribution system together. Researcher [12], in their view said distribution line conductors consist of feeders, distributors and service mains. According to [13], the distribution system is divided into two: the primary and secondary distribution systems. In the view of [14], the distribution substation is the first component that transforms the sub transmission voltage to primary distribution voltage (33KV) and primary distribution lines take the energy one step closer to the consumption areas. In the perspective of [15], the secondary distribution system consists of distribution transformers, distributors, service mains etc., the distribution transformer receives energy supply from primary distribution system and transform the voltage to 0.415KV three phase supply and 0.240KV single phase and neutral mostly for commercial and residential utilization.

Researcher, [16] analysed the daily outage data collected for a period of twelve (12) months (April 2003 to April 2004), from these data; the type, number and duration of the outages were documented; the plots of outage distribution of five 33KV feeders were obtained. Their forced outages were compared as well. In the perspective [17], Power losses due to the feeder outage were considered and the feeders, at each voltage level were investigated for power loss. The results obtained were discussed, possible reasons for the causes of the outages were presented and befitting recommendations and solutions were proposed.

III. MATERIALS AND METHODS

in course of the investigation of fault connected to Beneku, Abragada and Abor community 33KV Distribution Feeder in Delta State, the data on the installed capacity of the gas turbine was examined, the power rating of distribution transformers and singe line diagram was collected from Agip turbine that supply power the area, the fault current and line impedance was determined, symmetrical method was used for fault analysis, Electrical Transient analyzer program (ETAP) simulation software was used to achieved the desired result.

- Description of the Gas Turbine Network

The gas turbine has 2.5MVA, generating at 11/33kv distribution network connected to three (3) communities, namely: Beneku community, with two(2) transformers rating of 500Kva and 100Kva, with a route length of 5km, while Abalagada community, has one(1) transformer rating 500Kva, with a route length of 16KM. while Abor community has four(4) transformers rated at 500Kva and three(3) transformers at a rating of 300Kva in total seven(7) transformers, with a route length of 10KM. in every junction there is always an isolation, the gas turbine peak load was 1mega watt and a minimal load as low as 0.7mega watt.

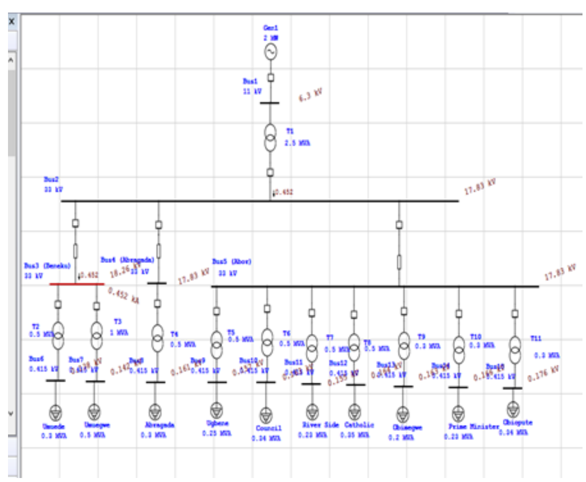

Figure 1: Pre-Fault Simulation on 33KV Distribution Feeder with Single Line to round Fault at Bus 3 (Beneku Community).

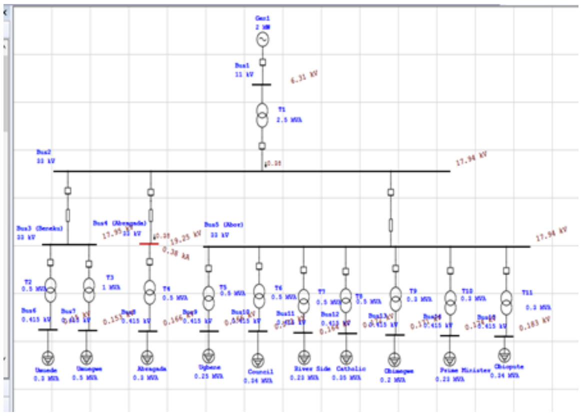

Figure 2: Pre-Fault Simulation on 33KV Distribution Feeder with Single Line to Ground Fault at Bus 4 (Abragada Community).

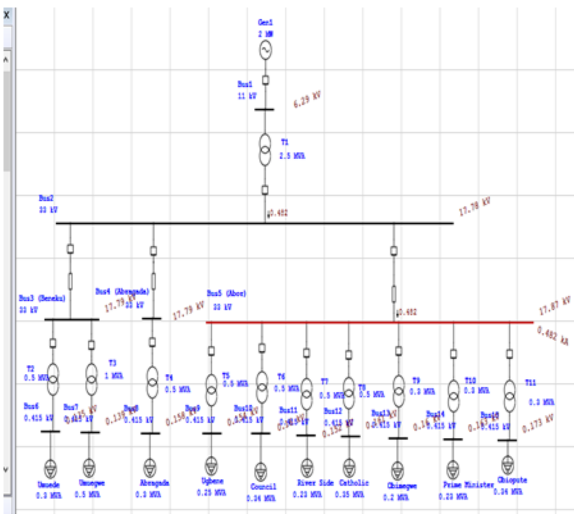

Figure 3: Pre-Fault Simulation on 33KV Distribution Feeder with Single Line to Ground Fault at Bus 3 (Abor Community).

- Determination of Sequence Components of Current

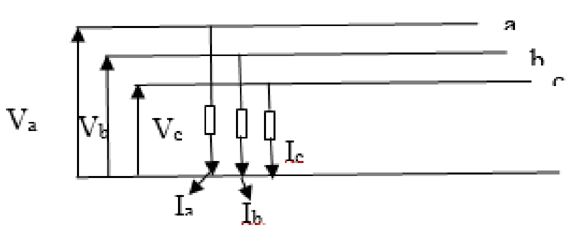

Figure 4: Distribution Network with Unbalanced Three-Phase Fault

The symmetrical component of the unbalanced three phases current I_a, I_b *and* I_c respectively was given as

$$I_a = I_{a_0} + I_{a_1} + I_{a_2} \quad (1)$$

$$I_b = I_{b_0} + I_{b_1} + I_{b_2} \quad (2)$$

$$I_c = I_{c_0} + I_{c_1} + I_{c_2} \quad (3)$$

[17]

Where

$I_{a_0}, I_{b_1}, I_{c_2}$ are the zero-sequence component of the current

$I_{a_1}, I_{b_1}, I_{c_1}$ are the positive - sequence component of the current

$I_{a_2}, I_{b_2}, I_{c_2}$ are the Negative- sequence component of the current

Using operator $\propto$ to express each component of I_b and I_c in terms of component I_a.

For positive – sequence

$$I_{b_1} = \propto^2 I_{b_1} \quad (4)$$

$$I_{c_1} = \propto I_{a_1} \quad (5)$$

For Negative- sequence

$$I_{b_2} = \propto I_{a_2} \quad (6)$$

$$I_{c_2} = \propto^2 I_{a_2} \quad (7)$$

For zero-sequence

$$I_{b_0} = I_{a_0} \quad (8)$$

$$I_{C_0} = I_{a_0} \quad (9)$$

Substituting equation (4)-(9) into equation (12) and (3) we have

$$I_a = I_{a_0} + I_{a_1} + I_{a_2} \quad (10)$$

$$I_b = I_{a_0} + \propto^2 I_{a_1} + \propto I_{a_2} \quad (11)$$

$$I_c = I_{a_0} + \propto I_{a_1} + \propto^2 I_{a_2} \quad (12)$$

Put in Matrix form

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \propto^2 & \propto \\ 1 & \propto & \propto^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a_1} \\ I_{a_2} \end{bmatrix} \quad (13)$$

Equation (13) can be writing as

$$[I_{abc}] = [A][I_{012}] \quad (14)$$

Where

$[I_{012}]$= sequence component of fault current

$[A]$= Transformation matrix

$[I_{abc}]$= Phase component of the fault current can be writing as

From equation (14), the sequence component of the fault current can be written as

$$[I_{012}] = [A^{-1}][I_{abc}] \quad (15)$$

Put in matrix form

$$\begin{bmatrix} I_{a0} \\ I_{a_1} \\ I_{a_2} \end{bmatrix} = 1/3 \begin{bmatrix} 1 & 1 & 1 \\ 1 & \propto & \propto^2 \\ 1 & \propto^2 & \propto \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (16)$$

Determination of sequence components of generator voltage.

From equation (16), the sequence component of generator voltage can be expressed as

$[I_{012}] = [A^{-1}][I_{abc}]$ (17)

Where

I_{abc} = is the generator phase voltage

A^{-1} = is the transformation matrix

- Determination of Sequence Component of Impedance

$$\begin{bmatrix} Z_{a_0} & 0 & 0 \\ 0 & Z_{a_1} & \propto^2 \\ 0 & \propto^2 & Z_{a_2} \end{bmatrix} \quad (18)$$

Where

Z_{a_0}= is the zerosequence impedance

Z_{a_1}= is the positive sequence impedance

Z_{a_2} = is the Negative sequence impedance

- Determination of Voltage at the Point of Fault

$$\begin{bmatrix} V_{a_0} \\ V_{a_1} \\ V_{a_2} \end{bmatrix} = \begin{bmatrix} E_{a_0} \\ E_{a_1} \\ E_{a_2} \end{bmatrix} - \begin{bmatrix} Z_{a_0} & 0 & 0 \\ 0 & Z_{a_1} & \propto^2 \\ 0 & \propto^2 & Z_{a_2} \end{bmatrix} \begin{bmatrix} I_{a_0} \\ I_{a_1} \\ I_{a_2} \end{bmatrix} \quad (19)$$

Equation (19) can be written as

$[V_{012}] = [E_{012}] - [Z_{012}][I_{012}]$ (20)

[17]

Where

$[I_{012}]$ = sequence component of current

$[Z_{012}]$ = sequence component of impedance

$[E_{012}]$ = sequence component of generator Voltage

- Determination of Single Line to Ground Fault

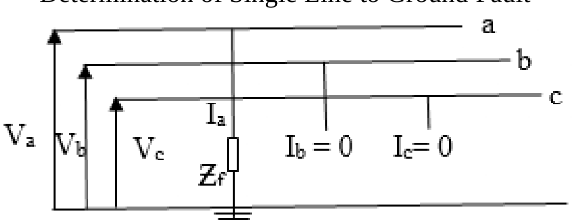

Figure 5: Single Line to Ground Fault

Single line to ground fault was considered. Figure 5, shows a single line to ground fault at point F. from the above diagram, only phase A is connected to the ground. Phase B and C are open circuit.

- Phase voltage at the point of fault (V_a)

$V_a = Z_f I_a$ (21)

Where

I_a= Fault current on phase A

Z_f= Fault impedance

Current at the Point of Fault

$I_a = I_{a_f}$ (22)

$I_b = I_c = 0$ (23)

Generator Phase Voltage at the point of Fault

$E_b = \propto^2 E_a$ (24)

$E_c = \propto E_a$ (25)

Sequence component of the current can be calculated from equation (25), we have

$$\begin{bmatrix} I_{a_0} \\ I_{a_1} \\ I_{a_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \propto & \propto^2 \\ 1 & \propto^2 & \propto \end{bmatrix} \begin{bmatrix} I_a \\ 0 \\ 0 \end{bmatrix} \Rightarrow \frac{I_a}{3}\begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \quad (26)$$

Sequence component of generator voltage can be calculated from equation (26), we have

$$\begin{bmatrix} E_{a_0} \\ E_{a_1} \\ E_{a_2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \propto & \propto^2 \\ 1 & \propto^2 & \propto \end{bmatrix} \begin{bmatrix} E_a \\ \propto^2 E_a \\ \propto \end{bmatrix} \Rightarrow \frac{E_a}{3}\begin{bmatrix} 0 \\ 3 \\ 0 \end{bmatrix} \quad (27)$$

$$\begin{bmatrix} E_{a_0} \\ E_{a_1} \\ E_{a_2} \end{bmatrix} \Rightarrow \frac{E_a}{3}\begin{bmatrix} 0 \\ E_a \\ 0 \end{bmatrix} \quad (28)$$

Sequence component of the phase voltage was given by equation (28)

$$\begin{bmatrix} V_{a_0} \\ V_{a_1} \\ V_{a_2} \end{bmatrix} = \begin{bmatrix} 0 \\ E_{a_1} \\ 0 \end{bmatrix} - \frac{1}{3}\begin{bmatrix} Z_{a_0} & 0 & 0 \\ 0 & Z_{a_0} & 0 \\ 0 & 0 & Z_{a_0} \end{bmatrix} \begin{bmatrix} I_{a_0} \\ I_{a_1} \\ I_{a_2} \end{bmatrix} \quad (29)$$

In algebraic form

$V_{a_0} = -\frac{I_a Z_{a_0}}{3}$ (30)

$V_{a_1} = E_a - \frac{I_a Z_{a_1}}{3}$ (31)

$V_{a_2} = 0 - \frac{I_a Z_{a_2}}{3}$ (32)

From equation (32)

$V_a = V_{a0} + V_{a1} + V_{a2} = Z_f I_a$ (33)

Substituting Equation (30), (31), and (32) into (33)

$I_a Z_f = -\frac{I_a Z_{a_0}}{3} + E_a - \frac{I_a Z_{a_1}}{3} - \frac{I_a Z_{a_2}}{3}$ (34)

$3I_a Z_f = -I_a Z_{a_0} + 3E_a - I_a Z_{a_1} - I_a Z_{a_2}$ (35)

$3E_a = I_a(3Z_f + Z_{a_0} + Z_{a_1} + Z_{a_2})$ (36)

Let $E_a = V_f$

$I_a = \frac{3E_a}{3Z_f + Z_{a_0} + Z_{a_1} + Z_{a_2}}$ (37)

Where

Z_{a_0} = zero sequence of the impedance

Z_{a_1}= positive sequence of the impedance

Z_{a_2}= Negative sequence of the impedance

Z_f = fault impedance

V_f= phase voltage at the point of fault

Sequence component of fault current from equation (26)

$$I_{a_0} = I_{a_1} = I_{a_2} = \frac{I_a}{3} \quad (38)$$

$$I_{a_0} = I_{a_0} = I_{a_2} = \frac{V_f}{3Z_f + Z_{a_0} + Z_{a_1} + Z_{a_2}} \quad (39)$$

Phase Voltage at the point of fault

$$V_a = V_{ao} + V_{a_1} + V_{a_2} \quad (40)$$

$$V_b = V_{ao} + \propto^2 V_{a_1} + \propto V_{a_2} \quad (41)$$

$$V_c = V_{ao} + \propto V_{a_1} + \propto^2 V_{a_2} \quad (42)$$

IV. RESULTS AND DISCUSSION

The result in figure 7, shows that Electrical Transient Analyzer Program (ETAP) simulation software was utilized to achieve the desired result for the improvement of the network by clearing the fault in figure 1,2 and 3, as shown in figure 6.

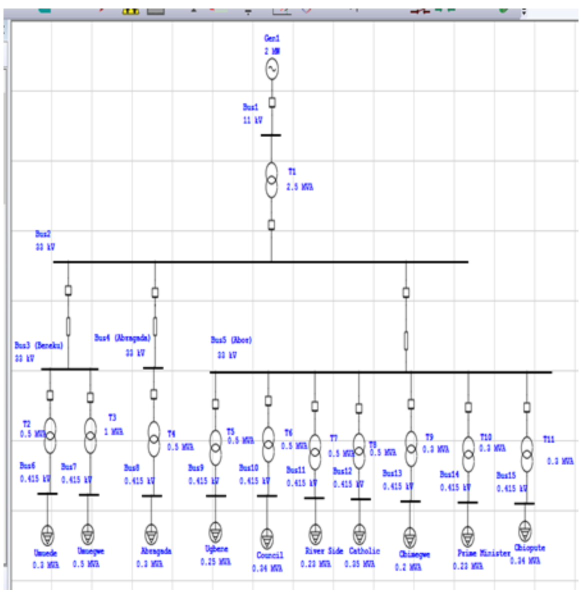

Figure 6: The Post- Fault 33KV Distribution Network for Beneku, Abragada and Abor community in Delta State, Nigeria.

The result in Figure 7, shows that the relationship between the demand in MVA and fault current in kA was linear.

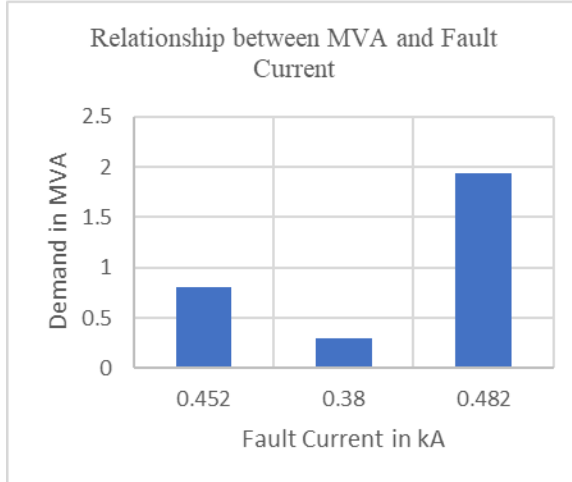

Figure 4.13: Relationship chart between MVA and kA from Simulation Result

CONCLUSION

In conclusion, the presence of fault in buses 3, 4 and 5, in figure 1, 2, and 3; present the network t Beneku, Abragada and Abor communities, shows that the fault currents for single line to ground faults were observed to be 0.452kA, 0.38kA and 0.482kA respectively against the nominal pre-fault current level. Impedance values for the affected buses were observed to be zero respectively.

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