# Reliability Analysis of Circuit Breakerin the Nigerian 330-kV Transmission Network.

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***Abstract***— **This paper is concerned with using the fault analysis to establish the requirements for the proper selection of circuit breaker; A Case Study of Power Holding company of Nigeria (PHCN) 330-kV Transmission Grid System. The work is modelled for Fault Analysis and it is written in a flexible MATLAB programs to accommodate addition or reduction in the Transmission Grid System. It aimed at establishing the Circuit Breaker Capacity at any point in the system. The result is then compared with the existing circuit breaker capacity of PHCN 330-kV system. The short-circuit fault is simulated by combining a solution of algebraic equations describing the changes in the network with a numerical solution of the differential equations. Two MATLAB programs were written and simulated; one for Lord Flow study to know the pre-fault bus voltages based on Gauss-Seidel Method; the other for Short Circuit Studies which made use of Thevenin's theorem application. The highest Circuit Breaker Capacity established by the result of this study is relatively lower and the investments needed for this are smaller compared with the normal practice with PHCN system. This reveals that PHCN system can be protected with this low capacity circuit breaker with a reduced cost effectiveness and equal sensitivity which is a break-through in terms of Circuit Breaker Capacity in the field of power system protection.**

***Keywords— Fault studies, circuit breaker, 330kV transmission grid, MATLAB program, Gauss Seidel load flow solution***

## I. INTRODUCTION

The current trends of erratic power supply and system collapse in Nigeria have made this study a paramount importance to the nation's power industry. The purpose of an electrical power system is to generate and supply electrical energy to consumers with reliability and economy. The operation of a power system is affected by disturbances that could be due to natural occurrences such as lightning, wind, trees, animals, and human errors or accidents. These disturbances could lead to abnormal system conditions such as short circuits, overloads, and open circuits. Short circuits, which are also referred to as faults, are of the greatest concern because they could lead to damage to equipment or system elements and other operating problems including voltage drops, decrease in frequency, loss of synchronism, and complete system collapse. There is, therefore, a need for a device or a group of devices that is capable of recognizing a disturbance and acting automatically to alleviate any ill effects on the system element or on the operator. Such capability is provided by the protection system. The protection system is designed to disconnect the faulted system element automatically when the short circuit currents are high enough to present a direct danger to the element or to the system as a whole. The objective of the system will be defeated if adequate provision for fault clearance is not made. The installation of switchgear alone is insufficient, discriminative protective gear, designed according to the characteristics and requirements of the power system must be provided to control the switchgear [1]. Security of supply, therefore, can be better by improving plant design, increasing the spare capacity margin and arranging alternative circuits to supply loads. Majority of the faults are unsymmetrical. However, the circuit breaker rated MVA breaking capacity is based on 3phase fault MVA. Since a 3phase fault inflicts greatest damage to the power system, except in a situation where a single line to ground fault is very close to a solidly grounded generator's terminal. In this instance the severity of single line to ground fault is greater than that of 3phase balance fault.

## II. BRIEF REVIEW OF SHORT-CIRCUIT ANALYSIS

Fault studies form an important part of power system analysis. In the context of electrical fault-calculation, a power system fault may be defined as any condition or abnormality of the system which involve the electrical failure of the primary equipment, the primary equipment implying equipment such as generators, transformers, busbars, overhead lines and cables and all other items of plant which operate at power system voltage (330kV for this case).

Faults on power system are divided into three-phase balanced faults and unbalanced faults. The different types of unbalanced faults are single line-to-ground fault (LG), line-to-line fault (LL), and double line-to-ground fault (LLG). The problem consists of determining the voltages and currents during various types of faults. The information gained from fault studies are usedfor proper relay setting and coordination. The three-phase balanced fault (LLL) information is used to select and set phase relays.

Majority of the faults are unsymmetrical and the current which a breaker must interrupt is usually asymmetrical since it still contains some of the decaying dc component [2]. However, the circuit breaker rated MVA breaking capacity is based on three-phase balanced fault MVA. Since a three-phase fault inflicts greatest damage to the power system, except in a situation where LG fault is very close to a solidly grounded generator's terminal. In this instance the severity of single line to ground fault is greater than that of three-phase balanced fault.

The condition of the power system during the fault condition can be explained from the equation for short circuit studies. The equation for the short circuit uses the sequence components theory in the method of calculation.

In an attempt to establish short circuit studies, various forms of faults were simulated to obtain the current which the breaker must interrupt and comparison was made between LLL fault and LG fault either of which is likely to cause greater damage to a power system. This current is properly called the required symmetrical interrupting capacity or simply the rated symmetrical short-circuit current. [3]

## III. PROBLEM FORMULATION (LOAD REPRESENTATION)

During sub-transient period, power system loads, other than motors are represented by the equivalent circuit as static impedance or admittance to ground.The symmetrical three phase fault current in per unit is given by

$$I_K(F)pu = \frac{V_K(0)}{X_{KK}} \qquad (1)$$

Where $V_K(0)$ is the per unit Perfault bus voltage and $X_{KK}$ = the p.u reactance to the point of Fault

The base current $I_B = \frac{S_B \times 10^3}{\sqrt{3}V_B}$ (2)

Where $S_B$ is the base MVA and $V_B$ is the line to line base voltage in kV

The interrupting rating of a circuit breaker was specified in KVA or MVA.

From (2), it implies that the interrupting KVA equal $\sqrt{3}$ times the kV of the bus to which the breaker is connected times the current which the breaker must be capable of interrupting when its contact part. This current is of course, lowers than the momentary current and depends on the speed of the breaker [2].

Also, for the purpose of short circuit analysis in order to select appropriate circuit breaker to clear a fault instantly before transient condition on a power system, pre-fault condition of the system (i.e, pre-fault voltages and currents) should be known and this can be obtained from the load flow solution for the power system. Detail of the initial value of the current for a constant current representation is obtained from model of fig 1.

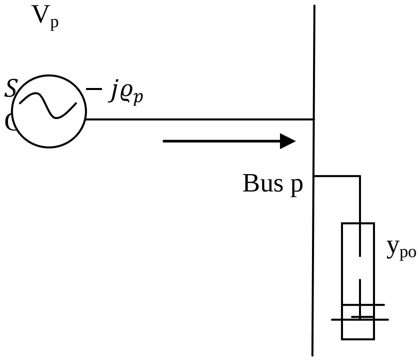


Figure 1: A typical fault model at bus P

$$I_{po} = \frac{P_p - jQ_p}{V_p^*} \qquad (3)$$

Where; $P_p$ and $Q_p$ = the scheduled bus load.

$V_P$ = the calculated voltage which can only be determined if $Q_{ip}$ is given or known

The injected current $I_{po}$ flows from bus P to ground, that is, to bus 0.

The magnitude and power factor angle of $I_{po}$ remain constant.

$$y_{po} = \frac{I_{po}}{V_p}.$$

(4)



## IV. NETWORK PERFORMANCE EQUATION

The Gauss-Seidel Method of solution used for the load flow equation can be applied to describe the performance of a network during a sub-transient period, using the bus admittance matrix with ground as reference. The voltage equation for bus P is given by:

$$V_p = \frac{(P_p - jQ_p)L_p}{V_p^*} - \sum_{q=1}^{p-1} YL_{pq}V_q^{k+1} - \sum_{q=p+1}^{n} YL_{pq}V_q^{k} \text{....(5)}$$

$$where; \quad YL_{pq} = Y_{pq}L_p; L_p = \frac{1}{Y_{pp}}$$

$$The\ term\ \frac{(P_p - jQ_p)}{V_p^*}\ in\ equation\ (5)\ represents\ the\ load\ current\ at\ bus\ P.$$

*for the constant load current representation,*

$$\frac{P_p - jQ_p}{(V_p^k)^*} = |I_{po}| < (\omega_p^k + \varphi_p) \text{.......................................(6)}$$

*where;* $\varphi_p$ *= the power factor angle,*

*and* $\omega_p^k$ *= the angle of voltage with respect to the reference.*

When the constant power is used to represent the load, ($P_p$ – $jQ_p$) $L_p$ will be constant but the bus voltage $V_p$ will change in any iteration [4]. When the load at bus P is represented by a static admittance to ground, the impressed current at the bus is zero and the

$$\frac{\left(P_p - jQ_p\right)L_p}{V_p^*} = 0 \qquad (7)$$

For a sub-transient analysis in short circuit studies, the parameters of equation (5) must be modified to include the effect of the equivalent element required to represent synchronous, induction and loads. The line parameters $YL_{pq}$ must be modified for the new elements and additional line parameter must be calculated for each new network element.

## V. METHOD OF SOLUTION

The methods and concepts employed to implement this work includes:

- Developing an algorithm and hence a programme for fault level calculation at the location of fault in a 330-kV transmission Grid system.
- Determine the fault current for various types of fault simulation.
- Recommend the appropriate circuit breaker capacity to clear any detected fault.

Note that it is necessary to do a load flow calculation before one can proceed on fault analysis. This is important so as to know the pre-fault voltages and currents necessary for further calculation. The network representation for the short circuit studies includes among other things, the Grid components parameter i.e the generators system buses, transmission lines and transformers. Modification of the admittance matrix to impedance matrix is done on the load flow calculation [4] to reflect fault analysis.

These pre-fault conditions can be obtained from the result of load flow solution by Gauss-Seidel iteration method using $Y_{BUS,}$ the flowchart of which is illustrated in Fig.2.

The pre-fault machine currents are calculated from load flow by Gauss-Seidel iterative method from:

$$I_{ki} = \frac{P_{ki} - jQ_{ki}}{V_{ki}^*}; i = 1,2,.........,m.....................................(8)$$

*where;*

$P_{ki}$ *and* $Q_{ki}$ = *the scheduled or calulated machine real and reactive terminal powers.*

$V_{ki}^*$ = *the last iteration voltage.*

$m$ = *the number of machines in the system.*

The network is then modified to correspond to the desired representation for short circuit studies. Being a linear network of several voltage sources, further calculation can be computed by application of Thevnin's theorem [5].

$$I^f = \frac{V^o}{jX''_{TH} + Z^f} \qquad (9)$$

## VI. COMPARISON OF SLG FAULT AND THREE-PHASE FAULT (LLL) CURRENTS

This comparison[5]is necessary because of the earlier statement in this project study that single line-to-ground fault is more severe than that of 3-phase fault if the fault is located very close to the terminal of a solidly grounded generator.

The fault impedance can be assumed to be zero because of the enormous effect of the fault current. In addition, if the impedances $Z_1$, $Z_2$ and $Z_0$ are assumed to be pure reactances ($X_1$, $X_2$ and $X_0$), then for a 3-phase fault.

$$I_a = \frac{E}{jX_1} \qquad (10).$$

*and that of single line – to – ground fault is given as;*

$$I_a = \frac{3E}{jX_1 + jX_2 + jX_0} \qquad (11).$$

**The three practical possibilities are as follow**;

i. Fault at the terminals of neutral solidly grounded generator, (for generator $X_0 << X_1$), and it is assumed that $X_1 = X_2$ for sub-transient condition which is the case for the short circuit studies. At this instance single line –to-ground fault is more severe than a 3-phase fault

ii. If a generator is grounded through a reactance $X_n$, this does not have any effect on a 3-phase fault current, but a single line-to-ground fault will have a fault current:

$$I_a = \frac{3E}{j\left(X_1 + X_2 + X_0 + 3X_n\right)}$$

iii. to this end the relative severity of 3-phase fault and single line-to-ground fault will depend on the value of $X_n$.

iv. For a fault on a transmission line (which is the case study) $X_0 >> X_1$ so that for a fault on a line sufficiently far away from the generator terminals, 3-phase fault current is more than single line-to-ground fault current.

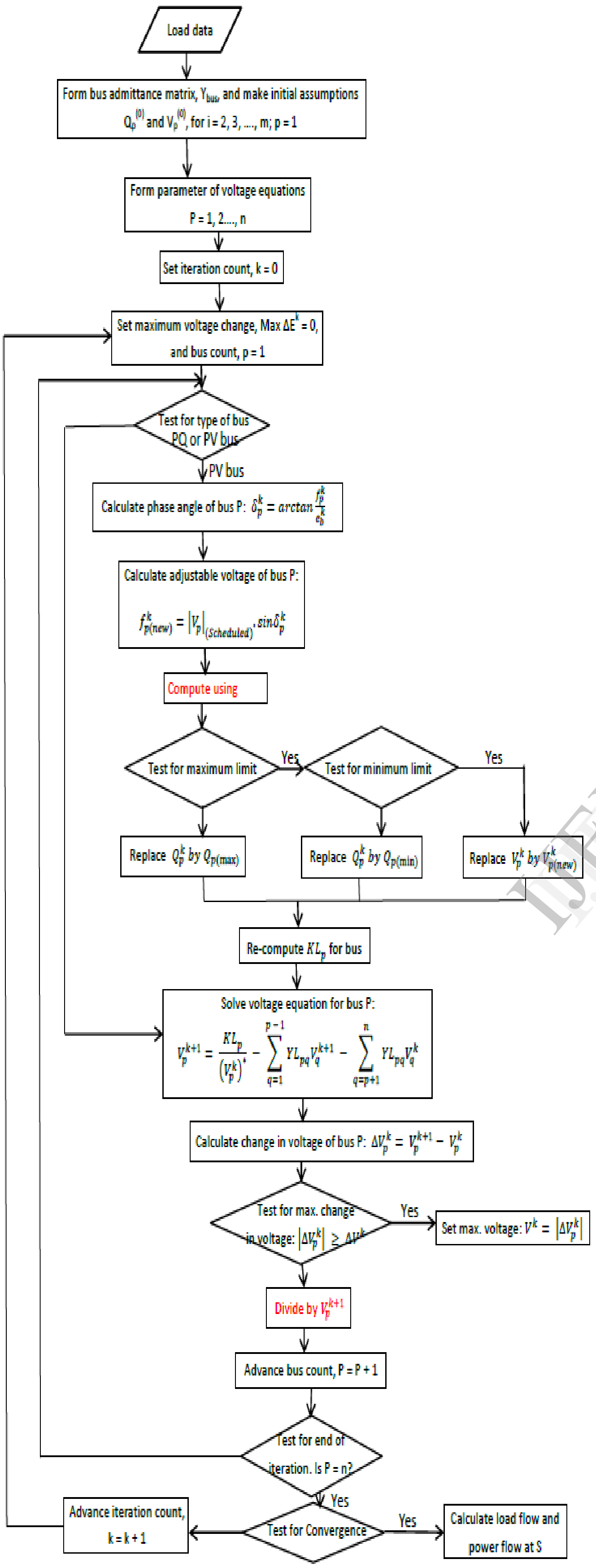


Figure 2: Flow Chart for Load-Flow Solution: Gauss-Seidel Iteration

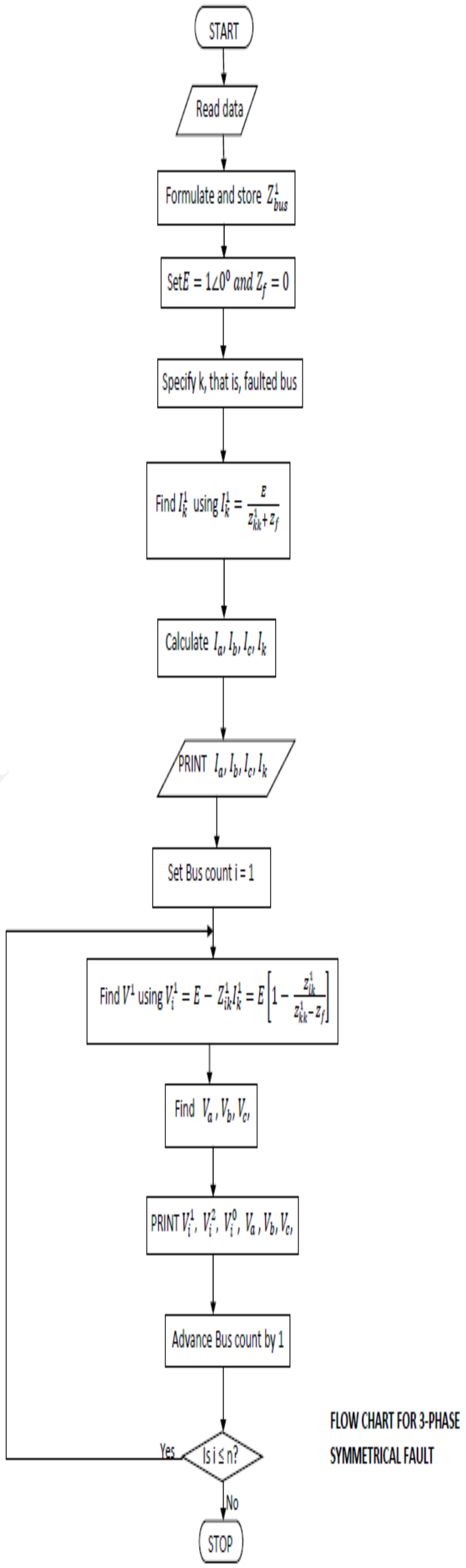


Figure 3: Flow Chart for 3-Phase Symmetrical Fault

## VII. RESULT OF SYSTEM MODELING

There is a necessity to have the knowledge of pre-fault voltages and currents in order to proceed with the calculation of the fault currents and hence achieving the aims of the research study. Hereunder are one-line diagram of the existing National 330-kV Network (Fig.4) and the systems data(Table) employed in the load flow calculation:

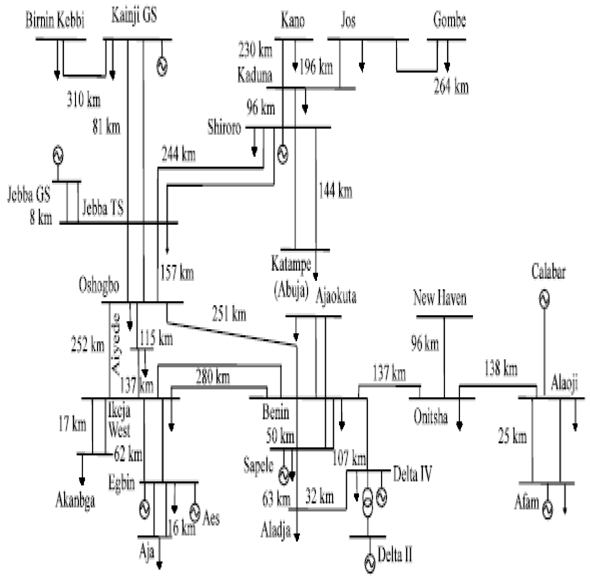


Figure 4: The 28-Bus System of the Nigerian Transmission 330-kV Grid as a Case Study [6]

Table 1: Transmission line data on 33kV, 100MVA base (All values are in per unit) [7]

| BUS - NO FROM | BUS - NO TO | FROM BUS | TO BUS | LENGTH(km) | R(pu) | X(pu) | ADMITTANCE (b/2) |
|---|---|---|---|---|---|---|---|
| 1 | 2 | Alaoji | Afam | 25 | 0.009 | 0.007 | 0.104 |
| 1 | 4 | Alaoji | Onitsha | 138 | 0.049 | 0.042 | 0.524 |
| 3 | 4 | New Haven | Onitsha | 96 | 0.003 | 0.0292 | 0.365 |
| 4 | 6 | Onitsha | Okpai | 80 | 0.009 | 0.007 | 0.104 |
| 5 | 4 | Benin | Onitsha | 137 | 0.0049 | 0.0416 | 0.521 |
| 5 | 7 | Benin | Ajaokuta | 195 | 0.007 | 0.056 | 0.745 |
| 5 | 10 | Benin | Sapele | 50 | 0.0018 | 0.0139 | 0.208 |
| 5 | 11 | Benin | Delta | 107 | 0.0023 | 0.019 | 0.239 |
| 5 | 14 | Benin | Omotosho | 120 | 0.0043 | 0.0365 | 0.228 |
| 5 | 18 | Benin | Oshogbo | 251 | 0.0089 | 0.0763 | 0.954 |
| 10 | 8 | Sapele | Aladja | 63 | 0.0023 | 0.019 | 0.239 |
| 11 | 8 | Delta | Aladja | 32 | 0.0023 | 0.019 | 0.239 |
| 12 | 5 | Ikeja | Benin | 280 | 0.0100 | 0.0779 | 1.162 |
| 12 | 9 | Ikeja | Aiyede | 137 | 0.0049 | 0.0416 | 0.521 |
| 12 | 13 | Ikeja | Papanlato | 30 | 0.0011 | 0.0091 | 0.057 |
| 12 | 14 | Ikeja | Omotosho | 160 | 0.0057 | 0.0486 | 0.304 |
| 12 | 15 | Ikeja | Akangba | 18 | 0.0022 | 0.0172 | 0.257 |
| 12 | 17 | Ikeja | Egbin | 62 | 0.0022 | 0.0172 | 0.257 |
| 12 | 18 | Ikeja | Oshogbo | 252 | 0.0049 | 0.0416 | 0.521 |
| 13 | 9 | Papalanto | Aiyede | 60 | 0.0021 | 0.0182 | 0.114 |
| 17 | 16 | Egbin | Aja | 14 | 0.0022 | 0.0172 | 0.257 |
| 18 | 9 | Oshogbo | Aiyede | 115 | 0.0041 | 0.0349 | 0.437 |
| 18 | 27 | Oshogbo | Jebba(TS) | 157 | 0.0056 | 0.0477 | 0.597 |
| 20 | 21 | Kaduna | Kano | 230 | 0.0082 | 0.0699 | 0.874 |
| 20 | 23 | Kaduna | Jos | 197 | 0.0070 | 0.0599 | 0.748 |
| 20 | 24 | Kaduna | Shiroro | 96 | 0.0034 | 0.0292 | 0.364 |
| 23 | 22 | Jos | Gombe | 265 | 0.0095 | 0.081 | 1.01 |
| 24 | 25 | Shiro | Katamp | 144 | 0.0 | 0.0 | 0.598 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | ro | e(Abuja) | | 052 | 401 | |
| 24 | 27 | Shiroro | Jebba(TS) | 244 | 0.0067 | 0.0702 | 0.927 |
| 26 | 28 | Benin Kebbi | Kainji | 734 | 0.0111 | 0.0942 | 1.178 |
| 27 | 19 | Jebba(GS) | Jebba(TS) | 8 | 0.0003 | 0.0022 | 0.0322 |
| 28 | 27 | Kainji | Jebba(TS) | 81 | 0.0029 | 0.0246 | 0.308 |

Table 2; Voltage-Control Bus Data

| BUS NO. | BUS NAME | QG | QD | QMIN | QMAX | VSP |
|---|---|---|---|---|---|---|
| | | SLACK BUS | | | | |
| 1 | KAINJI | 0.0000 | 0.0000 | -2.7900 | 2.7900 | 1.0500 |
| 2 | JEBBA | 0.0000 | 0.2400 | -3.2300 | 3.2300 | 1.0000 |
| 3 | SHIRORO | 0.0000 | 0.1800 | -2.0000 | 2.0000 | 1.0000 |
| 4 | SAPELE | 0.0000 | 0.0000 | -4.6700 | 4.6700 | 1.0000 |
| 5 | DELTA (IV) | 0.0000 | 0.3700 | -3.4300 | 3.4300 | 1.0000 |
| 6 | AFAM (IV) | 0.0000 | 0.0000 | -36700 | 36700 | 1.0000 |
| 7 | EGBIN | 0.0000 | 0.0000 | -5.8200 | 5.8200 | 1.0000 |

Table 3: Load Bus Data

| BUS NO | BUS NAME | ACTIVE | REACTIVE |
|---|---|---|---|
| | | POWER (PG) | POWER (QG) |
| 8 | JEBBA (T.S) | -0.7200 | -0.4300 |
| 9 | BIRNIN-KEBBI | -0.3900 | -0.1800 |
| 10 | KADUNA | -1.6100 | -0.8200 |
| 11 | KANO | -2.0400 | -0.8000 |
| 12 | JOS | -0.9800 | -0.3460 |
| 13 | GOMBE | -1.5300 | -1.0800 |
| 14 | OSOGBO | -1.5600 | -0.8800 |
| 15 | IBADAN | -1.8000 | -0.9300 |
| 16 | IKEJA-WEST | -5.1500 | -2.2900 |
| 17 | AJAOKUTA | 0.0000 | 0.0000 |
| 18 | BENIN | -2.4000 | -1.1200 |
| 19 | ONITSHA | -1.0200 | -0.4400 |
| 20 | ALADJA | -1.5600 | -0.8500 |
| 21 | ALAOJI | -2.1600 | -1.0400 |
| 22 | NEW-HAVEN | -1.1000 | -0.1800 |
| 23 | AKANGBA | -3.0750 | -1.5400 |
| 24 | AJA | 0.0000 | 0.0000 |
| 25 | KATAMPE (ABUJA) | 0.0000 | 0.0000 |
| 26 | AIYEDE | 0.0000 | 0.0000 |
| 27 | PAPALANTO | 0.0000 | 0.0000 |
| 28 | OMOTOSHO | 0.0000 | 0.0000 |

## VIII. LOAD FLOW RESULTS

The bus-bar pre-fault voltage, pre-fault current and pre-fault powers, which flow out of the bus bars, are tabulated in Table 4 hereunder

Table 4; Output of Load-Flow Results (in p.u )

| BUS NO. | VOLTAGE | POWER ANGLE | POWER FLOW | CURRENT |
|---|---|---|---|---|
| 1 | 1.0500 | 0.0000 | 2.4787 | 2.3605 |
| 2 | 1.0000 | -0.4060 | 7.2392 | 7.2394 |
| 3 | 1.0000 | -8.1200 | 3.6954 | 3.6954 |
| 4 | 1.0000 | 12.9979 | 7.0150 | 7.0150 |
| 5 | 1.0000 | 13.9877 | 3.6998 | 3.6998 |
| 6 | 1.0000 | 18.2990 | 4.4075 | 4.4075 |
| 7 | 1.0000 | 2.0316 | 4.3869 | 4.3869 |
| 8 | 1.1219 | -3.8503 | 0.8403 | 0.7443 |
| 9 | 1.0081 | -0.6090 | 0.4238 | 0.4208 |
| 10 | 1.0173 | -12.9984 | 1.8070 | 1.7760 |
| 11 | 1.0050 | -21.0013 | 2.1898 | 2.1982 |
| 12 | 1.0601 | -21.4268 | 1.0387 | 0.9522 |
| 13 | 1.0599 | -27.4552 | 1.8735 | 1.7563 |
| 14 | 1.0220 | -0.5700 | 1.7934 | 1.7518 |
| 15 | 1.0042 | -2.3010 | 2.0273 | 2.0202 |
| 16 | 0.9899 | -0.1259 | 5.6455 | 5.6960 |
| 17 | 1.0417 | 10.4510 | 0.0022 | 0.0020 |
| 18 | 1.0201 | 10.6305 | 1.1065 | 1.0860 |
| 19 | 1.0340 | 11.9994 | 0.4296 | 0.4068 |
| 20 | 0.9980 | 13.3385 | 1.8026 | 1.8015 |
| 21 | 1.0005 | 17.3005 | 2.4028 | 2.4018 |
| 22 | 1.0350 | 10.2956 | 1.1223 | 1.0764 |
| 23 | 0.9875 | -0.5500 | 3.4326 | 3.4798 |
| 24 | 1.0002 | 2.0225 | 0.0164 | 0.0168 |

## IX. RESULT OF SHORT CIRCUIT STUDIES

In the short circuit studies, a base current of **174.9546A** and a base voltage of **330kV** are computed together with the load flow output result of the pre-fault condition in the input data for the various fault current calculations using the Power System Matlab Programming.[9].

Simulations were made for different types of short circuit faults i.e, 3-phase fault; single line-to-ground fault, line-to-line fault and double line-to-ground fault. The summary of is shown in Table 5.

**Fault Current Result (IN ACTUAL VALUE)**

**BASE CURRENT = 1,749.546kA**

**BASE MVA = 100MVA**

**BASE VOLTAGE = 330kV**

TABLE 5: TYPE OF FAULT (SUMMARY)

| BUS NO. | 3-PHASE | SLG. | LL. | DLG |
|---|---|---|---|---|
| 1 | 21878 | 11296 | 19335 | 19684 |
| 2 | 11688 | 4321 | 9897 | 10369 |
| 3 | 12082 | 6345 | 9879 | 9802 |
| 4 | 15568 | 8442 | 12680 | 12582 |
| 5 | 9157 | 4913 | 7723 | 7675 |
| 6 | 2312 | 1382 | 2255 | 2196 |
| 7 | 24989 | 13021 | 21958 | 22013 |
| 8 | 2228 | 1180 | 2012 | 2032 |
| 9 | 10012 | 5014 | 9146 | 8887 |
| 10 | 5826 | 2798 | 4988 | 5102 |
| 11 | 1895 | 894 | 1687 | 1698 |
| 12 | 1768 | 852 | 1485 | 1551 |
| 13 | 1062 | 598 | 986 | 993 |
| 14 | 8896 | 4140 | 7734 | 7984 |
| 15 | 28984 | 13982 | 24968 | 25437 |
| 16 | 21787 | 9603 | 18475 | 19004 |
| 17 | 5719 | 2870 | 4970 | 5042 |
| 18 | 20593 | 10143 | 18042 | 18275 |
| 19 | 3678 | 1830 | 3234 | 3290 |
| 20 | 9006 | 4367 | 7911 | 7960 |
| 21 | 2218 | 1150 | 2019 | 2050 |
| 22 | 2462 | 1146 | 2203 | 2239 |
| 23 | 25432 | 11951 | 22204 | 22597 |
| 24 | 20998 | 10246 | 18269 | 18804 |

From the summarized result in Table 5 above, it can be inferred that 3-phase fault causes greatest magnitude of fault current to the system and hence, should be a point of reference upon which the circuit breaker to clear faults on 330kV transmission line is based.

## X. CONCLUSION AND RECOMMENDATION

To select the most appropriate size of Circuit Breaker for the Grid System, it has to be borne in mind that rated momentary current and rated symmetrical interrupting currents are required for the computation of circuit breaker ratings. Symmetrical current to be interrupted is computed by using sub-transient reactance for synchronous generators. Momentary current (rms) is then calculated by multiplying the symmetrical momentary current by a factor of 1.6 to account for the presence of D.C. offset current.

The 3-phase short circuit MVA to be interrupted can be computed as in the following equation [8]

$$MVA_{sc}(3-phase) = \sqrt{3} \times V_{pf1} \times I_{sc}.$$

*where;*

$$MVA_{sc}(3-phase) = 3-phase\ short\ circuit\ MVA.$$

$$V_{pf1} = \mathrm{Pr}e-fault\ line\ voltage\ in\ kV.$$

$$I_{sc} = Short\ circuit\ current\ in\ kA.$$

If voltages and currents are in per unit values on a 3-phase basis, then,

$$MVA_{sc}\ (3\text{-phase}) = |V|_{pre\text{-}fault} \times |I|_{sc} \times MVA_{base}$$

For example: The Short Circuit Current from the output result of the program for the short circuit studies is 29036A with a pre-fault voltage of 331.4520kV.

$$MVA_{sc}(3-phase) = \sqrt{3} \times V_{pf1} \times I_{sc}.$$

$$= \sqrt{3} \times 330kV \times 28{,}971kA$$

$$= 16{,}559MVA$$

## XI. CONCLUSION

From the above, and as a result of the research study, it can be concluded that the Circuit Breaker capacity for PHCN 330kV Transmission Grid should be 20,000MVA. The research result is a break-through in terms of Circuit Breaker Capacity in the field of Power System Protection.

The Birnin-Kebbi bus (B8) on which the receiving end voltage is higher than the sending end voltage, it is agreed upon and confirmed that the line is an open-ended one. This is what causes the abnormality. The solution to it is to connect a reactor to the line.

## XII. RECOMMENDATIONS

From the Nameplate of a $Sf_6$ Gas Circuit Breaker (manufactured by GEC ALSTHOM T & D) on 330kV Transmission Line at the Area Transmission station in Osogbo:

Line Voltage $V_L$ = 362kV,

Frequency f = 50Hz,

Short Circuit Current $I_{sc}$ = 40kA

Line Current $I_L$ = 400A,

Current Interruption Capacity = 3,150A.

From the above data, the capacity of the Circuit Breaker is calculated to be 25,080.09569MVA. This is too high compared with the result of this project (i.e, 20,000MVA capacity) and it will be expensive in term of cost. The higher value of 25,080.09569MVA apart from cost, it will be more insensitive to any fault detected.

It is therefore recommended that the result of this paper should be of value to PHCN in the daily operation of the National Grid.

## REFERENCES

[1] W. D. Stevenson, Element of Power System Analysis, McGraw-Hill New York, 1982.
[2] J. J. Grander, and W. D. Stevenson, Power System Analysis, New York. McGraw-Hill, 1994
[3] H. Saadat "Power System Analysis" Published by McGraw-Hill publishing company limited, New York 2006.
[4] Braess, D. and Grebe, E. A. "Numerical Analysis of load-Flow Calculation Methods", .IEEE Trans, 1981 July, No. 7, Vol. Pas-100, pp. 3642-3647.
[5] B. R. Gupta, Power System Analysis and Design, Revised Edition, 2011
[6] PHCN National Control Centre Oshogbo, 2010, one line diagram of the 28 bus systems of Nigerian Transmission 330-kV Grid
[7] PHCN Line Parameters for 330-kV Circuits, 2011.
[8] I. J. Nagrath and D. P. Kothari, Power System Engineering, Fifth Print, 1998
[9] Brown, H. W., et al, Digital Calculation of Three-Phase Short –Circuits by Matrix Method, AIEE Trans, 1960, Vol. 79, pp. 1277