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**Original Research Article**

# Contingency Assessment of Medium Voltage Distribution System

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## ABSTRACT

*A power distribution network is simply an inter-connection of 33/11 kV power transformers, network in-feeds, distribution station buses and the loads. The security of such a system is of great consideration in power utilities. Thus, contingency analysis is often used to determine the security of such system. Several methods used in analyzing power system security include linear programming (LP), least squares (LS), decision trees (DTs), artificial neural network (ANN) etc. These methods were observed from literature to take a long computational period. Therefore, this paper presents a contingency assessment of medium voltage distribution network using Newton–Raphson (NR) technique of NEPLAN software. The approach involves carrying out of power flow analysis of the case study network. This analysis considered four scenarios; base case, case 2, case 3, and case 4 which are respectively defined as system operating under normal condition, abnormal operating condition without contingency, N-1 contingency, and N-2 contingency respectively. The results of the four cases show that contingency has negative effects on power equipment and the customers. The details of these results are presented. This contingency analysis thus provides reliability evaluation of the network while solutions to problems emanating due to contingencies are solved by utility company for revenue improvement.*

## 1. INTRODUCTION

System security is concerned with facilities that allow monitoring and reliable operation of a power system. The three functions of system security which are often carried out in control stations include system monitoring, contingency, and corrective action analysis (Mander and Virdi, 2017; Eltamaly, *et al.,* 2018). System monitoring provides system operators the up-to-date information about operational conditions of the transmission or distribution network. Equipment is provided to monitor the system parameters such as power flow, currents, voltages, as well as observing the condition of switches, circuit breakers and other allied equipment in the system (Adepoju *et al.,* 2017; Ajenikoko *et al.,* 2019; Adesina *et al.,* 2020a). Digital computers play a vital role in this regard by gathering the telemetry data, process, and stores. They also display information on display monitors and raises alarm in case of an overload or when voltage limit is exceeded. Typically, a grid control center is equipped with a supervisory control and data acquisition (SCADA) (Eseosa and Odiase, 2012). SCADA minimizes operators that monitor high voltage transmission and the generation system and correct any overloads or over-voltages.

Modern computers used in power system's operations are incorporated with contingency analysis software (CAS) (Mandloi and Jain, 2014). CAS model likely system problems before such trouble arise. The CAS are based on power system models and are often used in studying the outage events and consequently alert the system operator to overloads or over voltages.

Corrective action is required from the operators to alter the system operation when overload condition or the contingency analysis program predicts or display a serious problem which could lead to outage. Typical example of such a corrective action is shifting generation from one generating unit to another. This action can cause power flow to change and thus altering the loads of the overloaded lines (Afolabi *et al.,* 2015).

In power systems, be it generation, transmission, or distribution, it is important to put in place mechanisms that ensure a reliable operation of the system. However, where an unexpected disruption occurs, the engineer's contingency plan is often used as solution of the problem. Therefore, contingency solution offers an opportunity of alternative method and easy recovery approach so that if there exist a contingency, necessary resources are on ground to restore the system back to normal operation within the shortest possible time (Rani, 2016; Liu *et al.,* 2018; Yorino *et al.,* 2018).

Delson and Shahidehpour (1992) worked on linear programming applications to power system engineering analysis and demonstrated on its potential for future use. This study itemized three areas of interest: minimizing loss by allocating reactive power to the system, power generation load scheduling, and exploring capital investments on equipment in planning power generation. The authors observed and advised that system planning models must include financial flows using the linear programming method for capital budgeting. The reasons for this were illustrated with examples showing the effect of capital market conditions on engineering economic decision. However, this technique lacks computational feasibility and is slow in convergence. Soni, *et al.* (2016) introduced a well-organized learning technique for static security assessment of a large power network. This technique employs the least square-support vector machine (LS-SVM) to rank the contingencies which enhanced the prediction of the network severity level. The authors emphasized that the contingency severity was measured by two indices: line MVA performance index and Voltage-reactive power performance index. The work of SVM was categorized into two steps; the estimation of the two indices under different operating scenarios and the contingency ranking determination based on the values of indices obtained. The technique was observed to be slow in convergency and took a longer time to compute security assessment parameters accurately. Artificial Intelligence (AI) methods have been used for security analysis in power system network. Tomin *et al.* (2016), applied self-organization feature map and multi-layered feed forward network to solve problems of static security analysis. Also, Kalyani and Swarup, (2009a), Kalyani and Swarup, (2009b), and Kalyani and Swarup, (2013) respectively used radial basis function, support vector machine and decision trees to solve problems on networks security assessment. These studies revealed some useful information that are necessary for remedying insecure conditions in the network. However, the techniques also lack computational feasibility and accuracy.

The Nigerian power system is characterized by deficiencies caused by factors that include socio-political, structural, and financial. Most power stations operate below 50% of installed capacity. Therefore, it becomes necessary to assess the security level of such power system during contingencies. Consequently, this research aims to model a distribution system using NEPLAN software of Newton–Raphson (N-R) technique to improve the network security. Four case study were considered, and the approach involves carrying out of power flow analysis of the case study as base case (no contingency with normal operating condition), a case of no contingency but with abnormal operating condition, (case 2), a case of single line N-1 contingency, (case 3) and a case of double lines N-2 contingency, (case 4). The N-R technique is known to be faster in convergency and by this action minimize the computational time. It also gives accurate and reliable results.

## 2. METHODOLOGY

### 2.1. Contingency Problem Formulation

Static security analysis uses power flow equations to solve for various categories of disturbances. In power systems with normal operating conditions, the constraint in Equations (1) and (2) must be satisfied (McCalley *et al.,* 2011):

$$\sum_{i=1}^{Ng} P_{Gi} = P_D + P_{Loss} \tag{1}$$

Subject to:

$$\begin{aligned} &P_{Gi}^{Min} = P_{Gi} \le P_{Gi}^{Max} && i = 1,2,\ldots\ldots Ng \\ &V_k^{Min} \le V_k \le V_k^{Max} && k = 1,2,\ldots\ldots Nb \\ &P_{km} \le P_{km}^{Max} && for\ \forall\ branch\ k-m \end{aligned} \tag{2}$$

where $P_{Gi}$ = active power generated at node $i$, $P_D$ = system demand, $P_{loss}$ = active power loss in transmission, $V_k$ = voltage magnitude at node $k$, $P_{km}$ = active power flow between node k and m, $N_G$ = total generators in the network, $N_B$ = number of nodes in the network, $N_g$ = number of generators, $P_{Gi}^{Max}$ = maximum limit of power generated at node $k$, $P_{Gi}^{Min}$ = minimum limit of power generated at node $k$, $V_k^{Min}$ = minimum limit of voltage at node $k$, $V_k^{Max}$ = maximum limit of voltage at node $k$.

In optimization solution method of a contingency, severity index (SI) are used to analyze the security status of the power distribution system. This expresses the stress on the distribution system in the post contingency. Very often, reliable results are obtained using the functions (F) described in Equations (3) to (7) (Mishra and Khardenvis, 2012).

$$F = Min(SI) \tag{3}$$

$$Min\ SI = \alpha \cdot f_1 + \beta \cdot f_2 \tag{4}$$

$$f_1 = \sum_{i=1}^{Nb} \frac{W_{vi}}{2n} \left[ \frac{|V_i| - |V_i^{sp}|}{\Delta V_i^{\lim}} \right]^{2n} + \sum_{i=1}^{Ng} \frac{W_{Qi}}{2n} \left[ \frac{Q_i}{Q_i^{Max}} \right]^{2n} \tag{5}$$

$$f_2 = \sum_{2n}^{NL} \frac{W_{Li}}{2n} \left[ \frac{S_i^{Post}}{S_i^{Max}} \right]^{2n} \tag{6}$$

$$\alpha + \beta = 1 \quad for\ 0 < \mu \le 1 \tag{7}$$

Where $F$= objective function, SI = severity Index of line overloads, $f_1$ = power performance index of voltage-reactive, $f_2$ = performance index of line MVA, $\mu$ = the weight operator, W = active non-negative weighting factor, $n$ = order of the exponent for penalty function, $V_i^{sp}$ = specified voltage magnitude at node $I$, Vi = voltage magnitude at node $i$, $\Delta Vi^{\lim}$ = change in voltage limit at node $i$, $Q_i^{\max}$ = maximum reactive power at node $i$, $S_i^{Max}$ = maximum voltampere at node $i$, $S_i^{Post}$ = post iteration voltampere at node $i$, $\alpha$ and $\beta$ = weighing coefficients of the objective.

The nonlinear power flow equations described in Equations (8) and (9) are also termed equality constraints:

$$P_{Gi} - P_{Di} - \sum_{i=1}^{N} |V_i||V_j||Y_{ij}| Cos(\theta_{ij} - \delta_i + \delta_j) = 0 \tag{8}$$

$$Q_{Gi} - Q_{Di} - \sum_{i=1}^{N} |V_i||V_j||Y_{ij}| Sin(\theta_{ij} - \delta_i + \delta_j) = 0 \tag{9}$$

Where $P_{Gi}$ = active power generation at $i^{th}$ node, $P_{Di}$ = active power Demand at $i^{th}$ node, Vi= voltage magnitudes at the $i$th node, $\delta_i$= voltage angle at the $i^{th}$ node, $\delta_j$ = voltage angle at the $jth$ node, $V_j$ = voltage magnitudes at the $jth$ node, $\theta_{ij}$= angle between buses $i$ and $j$ in the admittance matrix, $Q_{Di}$ = reactive power demand at $i$th node $Q_{Gi}$= reactive power generation at the $i^{th}$ node, and N= number of nodes in the network.

The inequality constraints represent the system operational and security limits. Thus, inequality constraints have the following bounds for generation, transmission, and distribution:

1. For generation, generator bus reactive power outputs, active power outputs, and voltages are bounded by their lower and upper values as in Equations (10) to (12):

$$V_{Gi}^{Min} \le V_{Gi} \le V_{Gi}^{Max} \qquad i = 1,....,\ NG \tag{10}$$

$$P_{Gi}^{Min} \le P_{Gi} \le P_{Gi}^{Max} \qquad i = 1,....,\ NG \tag{11}$$

$$Q_{Gi}^{Min} \le Q_{Gi} \le Q_{Gi}^{Max} \qquad i = 1,....,\ NG \tag{12}$$

2. For distribution, the constraints include the constraints of voltages at load buses as in Equation (13).

$$V_{Li}^{Min} \le V_{Li} \le V_{Li}^{Max} \qquad i = 1,....,\ NL \tag{13}$$

3. For transmission lines loading, it is given in Equation (14)

$$S_i \le S_i^{Max} \qquad i = 1,....,\ nl \tag{14}$$

## 2.2. N-1 Distribution Line Contingency Analysis

Newton-Raphson power flow is often performed for transient stability of the distribution system (as base case) to obtain system conditions prior to the contingencies. Thereafter, an N-1 contingency would be introduced into the system to check the performance during failure of the components such as transformers, generators, or transmission lines. The severity index of single line contingency can be obtained using voltage-reactive power performance index and line MVA performance index as in Equations (15) and (16) (Mishra and Khardenvis, 2012):

$$P_{IVQ} = \sum_{i=1}^{Nb} \frac{W_{Vi}}{2n} \left[ \frac{|V_i| - |V_i^{sp}|}{\Delta V_i^{\lim}} \right]^{2n} + \sum_{i=1}^{Ng} \frac{W_{Qi}}{2n} \left[ \frac{Q_i}{Q_i^{Max}} \right]^{2n} \tag{15}$$

and

$$\Delta_i^{Lim} = V_i -_i^{Max} \quad \text{for} \quad V_i > V_i^{Max} \quad \text{and} \quad \Delta_i^{Lim} = V_i^{Min} - V_i \quad \text{for} \quad V_i < V_i^{Min}$$

$$P_{LMVA} = \sum_{i=1}^{NL} \frac{W_{Li}}{2n} \left[ \frac{S_i^{Post}}{S_i^{Max}} \right]^{2n} \tag{16}$$

For $S_L < S_L^{Max} \qquad L = 1,2.....,\ NL$

Subject to the following set of conditions:

For $P_{IVQ} < 1$ and $P_{LMVA} < 1$; The system is secure

For $P_{IVQ} > 1$ and $P_{LMVA} > 1$; The system is insecure.

Where $P_{IVQ}$ = voltage-reactive power performance index, $P_{LMVA}$ = line MVA performance index and $S_L$ = voltage amperes of the loaded node L

## 2.3. Description of the Case Study

Eko electricity distribution company (EKEDC) is a leading electricity company that provide electricity supply to Nigerian citizens in Lagos area of Nigeria. This company was approached for the provision of the data used in this study. Thus, the set up in Figure 1 which was used as case study network was obtained from EKEDC. The diagram in Figure 1 presents a 2 x 7.5 MVA 33/11 kV power injection substation's layout. It comprises of an incoming 33 kV line feeder as source of supply to the station which emanated from a 132/33 kV transmission station, a 33 kV bus bar, 2 Nos 7.5 MVA 33/11 kV power transformers, 6 Nos 11 kV outgoing feeders, and 1 Nos 11 kV bus section. Installed on each 11 kV outgoing feeder are protective equipment such as overcurrent, earth fault, overcurrent and earth fault relays to faults monitoring and to trip the feeder's circuit breaker in case of any fault, thus preventing damages to network equipment.

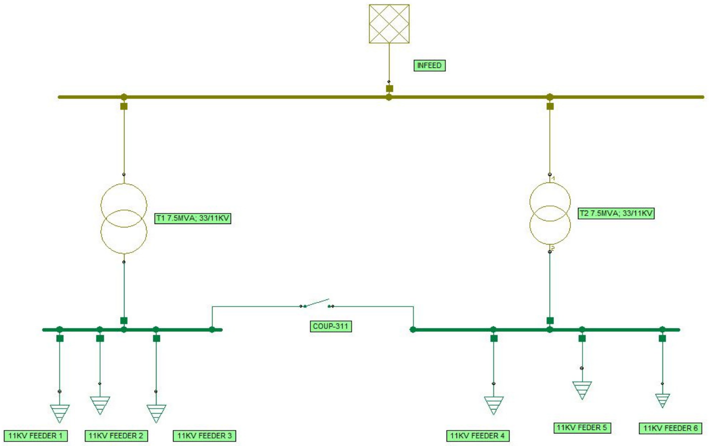

Figure 1: 2 x 7.5 MVA 33/11 kV power injection substation

## 2.4. Procedure for Network Simulations Analysis

The procedure used in carrying out the network modelling and simulations for contingency analysis are as follows.

1. Obtaining a schematic diagram and its data from the selected power utility company.
2. Development of a computer software for the analysis or use of a ready – made computer software such as NEPLAN, ETAP, etc. In this work, a ready-made NEPLAN software was used.
3. Modelling the obtained network using NEPLAN software on computer for the various scenarios of the contingency analysis e.g. N-1, or N-2 contingencies, etc.
4. Inputting the required data such as the loads on incoming 33 kV feeder and outgoing 11 kV feeders, the maximum allowable loads of each of the power transformers to avoid overloading and the Bus-section power rating.
5. The simulation for NEPLAN modelled network was carried out.
6. Results were obtained and recorded.
7. Steps 3 to 6 were repeated for the remaining three scenarios.

Therefore, following the steps in section 2.4, the selected network described in Figure 1 was modelled and simulations were carried out for the four cases considered i.e., base case, case 1, case 2, and case 3.

## 3. RESULTS AND DISCUSSION

The case study power system comprised of the following elements: two 15 MVA, 33/11 kV power transformers, one 33 kV feeder with breaker, two-line isolators, one bus section, and six 11 kV feeders with breakers (loads). If all these network elements are operating normally and there is no failure or loss of equipment, then this condition is referred to as 'No Contingency' and illustrated in Figure 2. The results of the system operation carried out under this condition are summarily presented in Table 1 which shows that the system was operating at steady state condition. It was observed that the loads on feeder 1, 2 and 3 are 0.09 kA, 0.071 kA and 0.077 kA respectively while the loads on feeder 4, 5, and 6 are 0.09 kA, 0.077 kA and 0.071 kA respectively. This imply that feeder 1 and 4 are loaded equally with 0.09 kA, feeder 2 and 6 are loaded equally with 0.071 kA and feeder 3 and 5 are loaded equally with 0.077 kA. The summation of loads on the 3 feeders connected to each power transformer gives the total load on that transformer. Therefore, power transformer percentage loading is obtained considering the installed capacity of that power transformer (15 MVA, 33/11 kV). Also, the active power drawn from each of the power transformer T1 and T2 is 3.7 MW while the recorded current consumption on each transformer is 238 A. Consequently, the above discussion accounted for the reason why the two-power transformer's percentage loading are equal (i.e., 64.34%). Hence, both active and reactive losses of the power transformers T1 and T2 are the same with the values, 0.0273 MW and 0.2716 MVAr respectively. The phase angle of T1 and T2 are the same i.e., 145.5 degrees. This in compliance with the requirements of paralleling transformers (Theraja and Theraja, 2005; Adesina *et al.*, 2020b). The active to reactive power ratio is bad compared to standard ratio 4:1 used in distribution supply (Adesina and Ebere, 2017). For example, in feeder 1, the ratio is 1.4: 0.868 which turned out to be 1.6:1. Also in feeder 5, the ratio is 1.2:0.744 which turned out to be 1.6:1. The low ratio often result to low voltage at customer end and loss of active power to the power utility. Therefore, for the customers to enjoy supply so that power utility can as well improve its revenue generation, it is important to install a capacitor bank at the injection substation to neutralize the reactive power on the line from source (Adesina and Ebere, 2017).

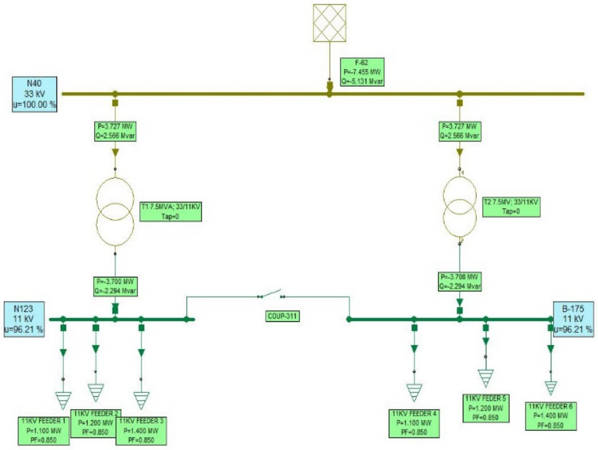

Figure 2: Case study 1 diagram showing all network elements working perfectly (No contingency)

Table 1: Case study 1 results of no contingency operation (base case)

| Element name | Type | Voltage (kV) | P (MW) | Q ($M_{var}$) | I (kA) | Angel I (°) | Load (%) | $PM_{loss}$ (MW) | $Q_{loss}$ ($M_{var}$) |
|---|---|---|---|---|---|---|---|---|---|
| F-62 | Network | 33 | -7.5 | -5.131 | 0.158 | 145.5 | - | - | - |
| T1 | TF | 33 | -3.7 | 0.237 | 0.238 | 145.5 | 60.34 | 0.0273 | 0.2716 |
| Feeder | 1 | 11 | 1.4 | 0.868 | 0.09 | -34.5 | - | - | - |
| Feeder | 2 | 11 | 1.1 | 0.682 | 0.071 | -34.5 | - | - | - |
| Feeder | 3 | 11 | 1.2 | 0.744 | 0.077 | -34.5 | - | - | - |
| T2 | TF | 33 | -3.7 | -2.294 | 0.238 | 145.5 | 60.34 | 0.0273 | 0.2716 |
| Feeder | 4 | 11 | 1.4 | 0.868 | 0.09 | 34.5 | - | - | - |
| Feeder | 5 | 11 | 1.2 | 0.744 | 0.077 | -34.5 | - | - | - |
| Feeder | 6 | 11 | 1.1 | 0.682 | 0.071 | -34.5 | - | - | - |

The results in Table 2 shows that the redundancy of power transformers helps to cater for the loads when anyone of the transformers failed. In this scenario, one of the 15 MVA 33/11 kV power transformers (transformer T2) was on outage due to faults, thus making all the loads on the 6 feeders to be on transformer T1. Consequently, the load on transformer T1 is zero while the percentage loading on this transformer T1 jumped up from 60.34% to 126.5% as seen in Table 1 and Table 2 respectively. This clearly show that transformer T1 is overloaded due to fault outage on transformer T2. In this condition, the active power and load drawn from power transformer T1 are 7.40 MW and 498 A respectively. The active and reactive losses of the power transformers T1 in circuit shoot up 0.12 MW and 1.1939 MVAr, which implied that the T1 is not working in good condition as this may affect the winding coil and formation of slots in the core of the transformer. Figure 3 fully describe the scenario.

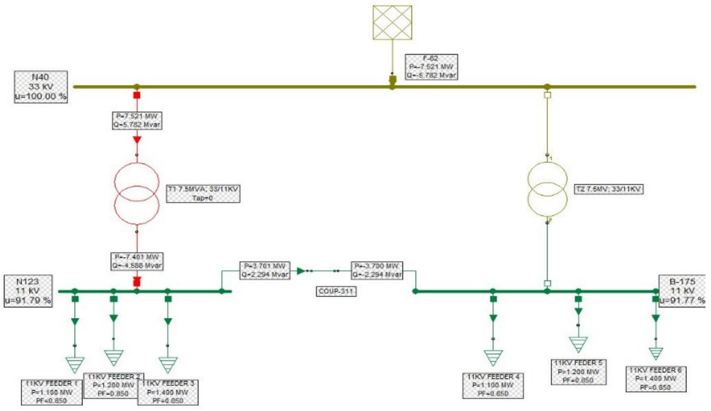

Figure 3: Case study 2 diagram showing abnormal system operation but no contingency

Table 2: Case study 2 results of no contingency but abnormal system operation

| Element name | Type | Voltage (kV) | P (MW) | Q ($M_{var}$) | I (kA) | Angel I (°) | Load (%) | $PM_{loss}$ (MW) | $Q_{loss}$ ($M_{var}$) |
|---|---|---|---|---|---|---|---|---|---|
| F-62 | Network | 33 | -7.521 | -5.782 | 0.166 | 142.4 | - | - | - |
| T1 | TF | 11 | -7.401 | -4.588 | 0.498 | 142.4 | 126.5 | 0.12 | 0.1939 |
| Feeder | 1 | 11 | 1.1 | 0.682 | 0.074 | -37.6 | - | - | - |
| Feeder | 2 | 11 | 1.2 | 0.744 | 0.081 | -37.6 | - | - | - |
| Feeder | 3 | 11 | 1.4 | 0.868 | 0.094 | -37.6 | - | - | - |
| T2 | 4 | 11 | 1.4 | 0.868 | 0.094 | -37.5 | - | - | - |
| Feeder | 6 | 11 | 1.2 | 0.744 | 0.081 | -37.5 | - | - | - |
| Feeder | 6 | 11 | 1.1 | 0.682 | 0.074 | -37.5 | - | - | - |
| Feeder | TF | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The operational results of N-1 Contingency are presented in Table 3. The N-1 contingency analysis was done to establish the response of a power network due to the loss of a major system element i.e. a 33 kV feeder ($F_1$). As a result of failure of 33 kV feeders ($F_1$), the 33 kV feeder ($F_2$) becomes the primary source of supply to the two 15 MVA power transformers $T_1$ and $T_2$ as shown in Figure 4. The percentage loading of the transformer $T_1$ and $T_2$ increased from their respective 60.34% (Table 1) to 65.17% and 65.18% (Table 3) respectively. This perhaps was due to more load allocation from generation/transmission to the 33 kV feeder ($F_2$) when 33 kV feeders ($F_1$) is on outage and this consequently gave rise to 2 additional 11 kV feeders that were previously suppressed loads to come up. This made the total outgoing 11 kV feeders to be eight in number instead of six as demonstrated in Figures 1 and 4. Line F2 has 85.25% loading which is relatively higher than the loading if both lines are actively energized. The line also has 0.00 MW active and 0.0021 MVAr reactive power losses. This is an implication that between the transmission station which is the source of supply and the injection station, the are no customer connection to the line. Hence, the loss on the line is approximately zero.

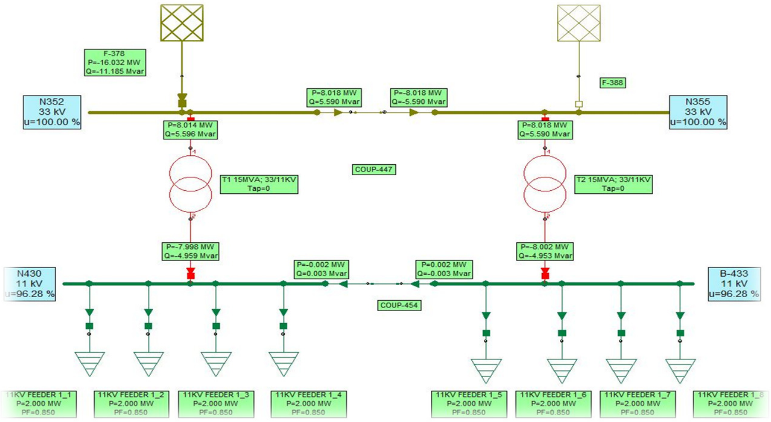

Figure 4: Case study 3 diagram showing N-1 contingency system operation

Table 3: Case study 3 results of N-1 contingency system operation

| Element name | Type | P (MW) | Q ($M_{var}$) | I (kA) | Angel I (°) | Load (%) | $PM_{loss}$ (MW) | $Q_{loss}$ ($M_{var}$) |
|---|---|---|---|---|---|---|---|---|
| F-378 | Network | -16.032 | -11.188 | 0.342 | 145.1 | - | - | - |
| L594 | Line F2 | 16.032 | 11.188 | 0.342 | -34.9 | 85.21 | 0 | 0.0021 |
| L599 | Line F1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| T1 | TF | 8.016 | 5.593 | 0.171 | 145.1 | 65.17 | 0.0159 | 0.6368 |
| Feeder | 1 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| Feeder | 2 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| Feeder | 3 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| Feeder | 4 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| T2 | TF | 8.016 | 5.593 | 0.171 | 145.1 | 65.18 | 0.0159 | 0.6368 |
| Feeder | 5 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| Feeder | 6 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| Feeder | 7 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |
| Feeder | 8 | 2 | 1.239 | 0.128 | -34.9 | - | - | - |

The results of power system operation for N-2 contingency are shown in Table 4. This contingency analysis evaluated the response of the power network after failure of 2 major network elements i.e a power transformer and a 33kV feeder in compares with the happenings in N-1 contingency. The power transformer ($T_1$) becomes overloaded after transformer ($T_2$) and the 33kV feeder ($F_2$) failed in the system. This scenario necessitates the use of bus coupler which links up all the eight 11kV feeders to power transformer ($T_1$). The load on transformer ($T_2$) was zero while that of power transformer ($T_1$) rose to 136.5%, indicating the transformer is overloaded. The high percentage loading of T1 (i.e., 136.5%) in this scenario 4 is different from the figure obtained in scenario 2 (i.e., 126.5%). This is also due to suppressed loads of 2 number 11 kV feeders added in scenario 3 (Figure 4). With only line F2 still in circuit, the system continuously maintains 0.00 MW active power losses with 0.002 MVAr as reactive power losses. The major effect of this scenario was o transformer T1 in circuit having a relatively high reactive power losses of 2.7992 MVAr and about zero active power losses. This scenario is generally illustrated in Figure 5.

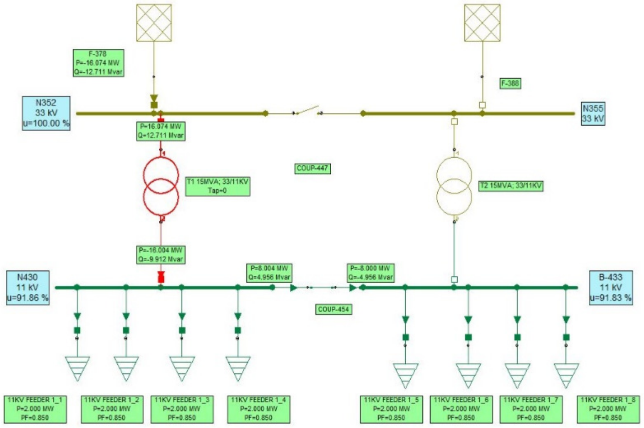

Figure 5: Case study 4 diagram showing N-2 contingency system operation

Table 4: Case study 4 results of N-2 contingency system operation

| Element name | Type | P (MW) | Q ($M_{var}$) | I (kA) | Angel I (°) | Load (%) | $PM_{loss}$ (MW) | $Q_{loss}$ ($M_{var}$) |
|---|---|---|---|---|---|---|---|---|
| F-378 | Network | -16.074 | -12.714 | 0.359 | 141.7 | - | - | - |
| L594 | Line F2 | 16.074 | 12.714 | 0.359 | -38.3 | 89.64 | 0 | 0.0023 |
| fL599 | Load F1 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| feeder | 1 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| feeder | 2 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| feeder | 3 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| feeder | 4 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| COUP-454 | Coupler | -8 | -4.956 | 0.538 | 141.7 | 0 | 0.0043 | 0 |
| T1 | TF | 16.074 | 12.711 | 0.359 | -38.3 | 136.65 | 0.07 | 2.7992 |
| T2 | TF | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| feeder | 5 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| feeder | 6 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| feeder | 7 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |
| feeder | 8 | 2 | 1.239 | 0.134 | -38.3 | - | - | - |

## 4. CONCLUSION

This research has presented an optimization approach for power systems security assessments with single line, double line, and equipment (transformer) contingency analysis to identify critical distribution outages to rightly take preventive actions using power system simulation (PSS) module (NEPLAN). Newton-Raphson load flow analysis was performed for transient stability of the distribution network. The approach was implemented on a selected Nigerian 33/11 kV distribution network substation. The results from the four test systems or scenarios are presented and discussed. The results also show how severe a possible line and transformer outage are in power system. The line outage with highest value indicates that the line outage has maximum chances of making system parameters to operate beyond the operating limits. Moreover, having used Newton - Raphson algorithm, apart from the fact that the convergency was shortly achieved, the results are also more accurate and reliable. Therefore, the results demonstrated the applicability of the PSS. However, this research has successfully implemented PSS module for optimal solutions for security assessment on the selected Nigerian 33/11 kV distribution network of Eko Electricity Distribution Company's (EKEDC), Lagos, Nigeria. This will help the concerned power utility company (i.e EKEDC) to determine their network security level within a short time and to also identify the distribution lines that needed much attention particularly in the area of system protection.

## 5. ACKNOWLEDGMENT

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## 6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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