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Contingency Analysis of 330kv Nigeria Network

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Abstract

This paper highlights the contingency analysis of Nigeria 330kV network to examine the risk of possible contingencies posed to the network under generators outage condition. The problems of the system in future are equipment malfunctions, under voltage at various buses, shortage of reactive power support, increased transmission losses and the tendency of system collapse. The design and simulation of the network was carried-out using power world simulator. The analysis was done using Newton-Raphson AC power flow method. Thereafter, three generators outage applied in the network was resolved using double circuit and reactive power compensation remedial actions. Consequently, a stable network that ensured adequate power delivery to the end users was achieved.

Keywords: Contingency Analysis, Power Flow, Transmission losses, Remedial actions, System collapse, Power world simulator

1. Introduction

Component outages in the distribution systems account for the absolute majority of the faults that result in an interruption of supply for the end consumers (Billinton and Allan, 1994). The consequences to modern society of a large interruption of supply (blackout) in the transmission system are considerable high. Important and vulnerable functions in the society, such as telecommunication, heating and water supply, normally function a few hours after an interruption of supply. Local backup generators can be available for some of the critical functions in the society, but this requires an organized distribution of fuel to the affected areas. The associated cost for the society of a large scale interruption is significant (Wacker and Billinton, 1989).

Since an outage event in the transmission system can propagate and paralyze the society in a widespread geographical area, the system has been constructed to meet the high needs of reliability. It is generally designed, operated and planned with the deterministic N- 1 criterion of contingency analysis, which is a rule according to which the system must be able to withstand the loss of any principal single component (ENTSOE, 2007). Clearly this criterion provides a security margin against unwanted conditions in the system.

As some propose for new sources of power in order to meet up the Nigeria energy demand, it is important to examine the security level of the existing grid in order to devise a more defensive approach of operation. Transmission Company of Nigeria (TCN), projected to have the capacity of delivering 12,500 MW in 2013, now has the capacity of delivering about 4800 MW of electricity. Nigeria has a generating capacity of 5,228 MW but with peak production of 4500 MW against a peak demand forecast of 10,200MW. This shows that if the generation sector is to run at full production, the transmission grid will not have the capacity to handle the produced power reliably (Nigeria Compass, 2013). This goes a long way to tell that the 330 KV transmission system is not running effectively as expected. Therefore to maintain and ensure a secure operation of this delicate system, the need for contingency analysis cannot be over emphasized.

2.0 Contingency analysis

Contingency Analysis (CA) in the simplest of term is the “what if” scenario analysis that determines the effect of electric components (elements) outage, provides information used to prioritize facilities and operating condition available to the electric power system.

Contingencies are defined as potentially harmful disturbances that occur during the steady state operation of a power system (Chary, 2011). Contingencies can lead to some abnormalities such as over voltage at some buses, over loading on the lines, which if are unchecked, can lead to total system collapse.
Power system engineers use contingency analysis to predict the effect of any component failure. Periodically, maintenance operations are carried-out on generating units or transmission lines. During this, a unit is taken offline for servicing. The effect of this forced outage on other parts of the system can be observed using contingency analysis.
Contingency analysis and risk assessment are very important task to assess the ability of the network to provide electric power of sufficient quality to customer. It is defined as potentially harmful for steady state operation of an electrical network that can result in possible loss of part of the network like buses, lines, transformer and power unit of any network area. These problems are concerns in the planning and operation of the power system. In the planning, contingency analysis is used to examine the performance of a power system and the need for new generation or transmission expansion due to load growth. In the operation, contingency analysis assists engineers to operate the power system at a secure operating point where equipment are loaded within their safe limits and power is delivered to customers with acceptable quality standards.
Severe fault can lead to wide spread of voltage drop, transformer tripping, line overload, system collapse or equipment malfunctions. To avoid these problems, contingency analysis must be studied with different contingency levels to determine the corrective action. Adding new var sources and transmission's equipment will improve the voltage profile, avoid transmission's equipment overloading and reduce transmission losses.
There are various methods of contingency analysis which include the following:

a. AC Load flow method
b. DC Load flow method
c. Z-Matrix method
d. Performance Index method

Of all the above listed methods, AC power flow calculation is considered to be deterministic method which is accurate compared to DC power flow method. In deterministic method, line outages are simulated by actual removal of lines. AC power flow method is accurate but computationally expensive and excessively demanding of computational time.

3.0 Formulation of power flow equations

The apparent power injected into any *i* named bus is given as

$$S_j = P_j + jQ_j \quad (1)$$

In terms of bus voltage and conjugate of bus current, the apparent power injected into bus $_j$ is given as

$$S_j = V_j I_j^* \quad (2)$$

where;

- P_j is the real power component of the power in bus $_j$
- Q_j is the reactive power component of the power in bus $_j$
- V_j is the voltage at bus $_j$
- I_j is the current at bus $_j$ while,
- I_j^* is the conjugate of current at bus $_j$

Combining equations (1) and (2) produces

$$P_j + jQ_j = V_j I_j^* \quad (3)$$

Usually, of the four parameters (real power, reactive power, bus voltage magnitude and voltage phase angle) only two are specified to identify the bus which predefines the type of bus in use. The current, $\mathbf{I}_j$ injected in or out of a bus is not specified and is initially unknown, so its conjugate I_j^* cannot be determined ab initio. This constraint limits the use of equation (3). Since V_j is often specified for some buses, its conjugate can be found. Hence equation (3) can be replaced with its mathematical equivalent as

$$P_j - jQ_j = V_j^* I_j \quad (4)$$

The application of Kirchoff's Current Law (KCL) to an interconnection of n buses, the expression for the current I_j injected into any *j* bus is given as

$$I_j = \sum_{k}^{n} Y_{jk} V_k \quad (5)$$

For $_j$, k = 1,2,3,..,n

Where, Y_{jk} is the admittance for the transmission line between buses $_j$ and *k*. The substitution of equation (5) into (4) gives

$$P_j - jQ_j = V_j^* \sum_{k}^{n} Y_{jk} V_k \quad (6)$$

Comparing terms;
P_i represents the real part while Q_j represents the negative imaginary part of the RHS of equation (6). Mathematically this becomes,

$$P_j = \text{real part of } V_j^* \sum_{k}^{n} Y_{jk} V_k \quad (7)$$

$$Q_j = -\text{ imaginary part of } V_j^* \sum_{k}^{n} Y_{jk} V_k \quad (8)$$

With $\mathbf{Y_{jk}} = \mathbf{G}_{jk} + j\mathbf{B}_{jk}$ recall that in their polar forms Y_{jk}, V_j^* and V_k are given as

$$Y_{jk} = |Y_{jk}|e^{j\theta_{jk}} = |Y_{jk}| < \theta_{jk} \quad (9)$$

$$V_j^* = |V_j|e^{-j\delta_j} = |V_j| <- \delta_j \quad (10)$$

$$V_j = |V_k|e^{j\delta_k} = |V_j| < \delta_k \quad (11)$$

where, θ_{ik} and δ_i are the phase angle of the admittance and the bus voltage respectively.
Substituting for Y_{jk}, V_j^* and V_k in equation (6) gives

$$P_j - jQ_j = |V_j|e^{-j\delta_j} \sum_{k}^{n} |Y_{jk}|e^{j\theta_{jk}} \ |V_k| e^{j\delta_k}$$

$$P_j - jQ_j = |V_j| \sum_{k}^{n} |Y_{jk}||V_k| \ e^{j(\theta_{jk} - \delta_j + \delta_k)}$$

This implies that

$$P_j - jQ_j = |V_j| \sum_{k}^{n} |Y_{jk}||V_k| \ e^{j(\theta_{jk} - \delta_j + \delta_k)} \quad (12)$$

For j, $k = 1,2,3,\ldots,n$
But noting that $|A|e^{ix} = |A|<x = |A|\cos x + j|A|\sin x$
Then equation (12) becomes;

$$P_j = |V_j| \sum_{k}^{n} |Y_{jk}||V_k| \cos(\theta_{jk} - \delta_j + \delta_k) \quad (13a)$$

$$Q_j = -|V_j| \sum_{k}^{n} |Y_{jk}||V_k| \sin(\theta_{jk} - \delta_j + \delta_k) \quad (13b)$$

For j, $k = 1,2,3,\ldots,n$
Equations (13a) and (13b) are called the power flow equations (Gupta, 2008).
In setting up the Newton-Raphson numerical method, the power-flow expressions of equations (13a) and (13b) are employed because these equations are more flexible and convenient to work with in developing and computing the elements of Jacobian matrix than the use of equation (12).

4.0 Modelling of line flows and losses

Once the number of iteration is complete, the computation of line flows and losses is implemented. To accomplish this, a different program is developed with the aid of the model derived. Thus, figure 1 is a one- line diagram of a transmission line between two buses *i* and *k* which is used as a model to derive the line flow and losses.

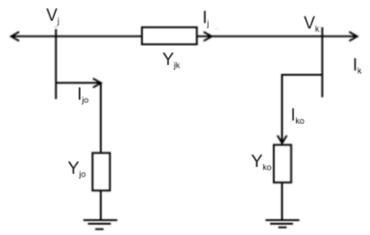

Fig. 1: Transmission line model for calculating line losses

If bus *j* was to have a higher voltage potential, then applying Kirchhoff's Current Law at bus *j* and defined in the positive direction of $j \rightarrow k$ gives the line current, I_{jk}, as

$$I_{jk} = I_j + I_{jo} = Y_{jk}\left(V_j + V_k\right) + Y_{jo}V_j \qquad (14)$$

Similarly, applying the same KCL at bus *k* for I_{jk} which is considered positive in the direction $k \rightarrow j$, this line current is given as

$$I_{kj} = -I_k + I_{ko} = Y_{jk}\left(V_k - V_j\right) + Y_{ko}V_k \qquad (15)$$

The complex power S_{jk} from bus *j* to *k* which represents the Line flow and that from *k* to *j*, S_{kj}, are given as

$$S_{jk} = V_j I_{jk}^* \qquad (16)$$

$$S_{kj} = V_k I_{kj}^* \qquad (17)$$

The power loss $\mathbf{S_{L\mathit{jk}}}$ in line *j* - *k* is the algebraic sum of the power flows determined from equation (16) and (17)

$$S_{Ljk} = S_{jk} + S_{kj} \qquad (18)$$

These equations are the mathematical model requirement for simulating load flow and line losses using Newton Rasphson iterative method as implemented with PowerWorld Simulator.

5.0 Network visualization

The single line diagram for the base case of Nigeria forty one bus network is shown in fig. 2 as captured from power world simulator. Base case voltage and line parameters used for modelling Nigeria 41 bus network (fig. 2) is represented in the table 1.0 and table 2.0 respectively

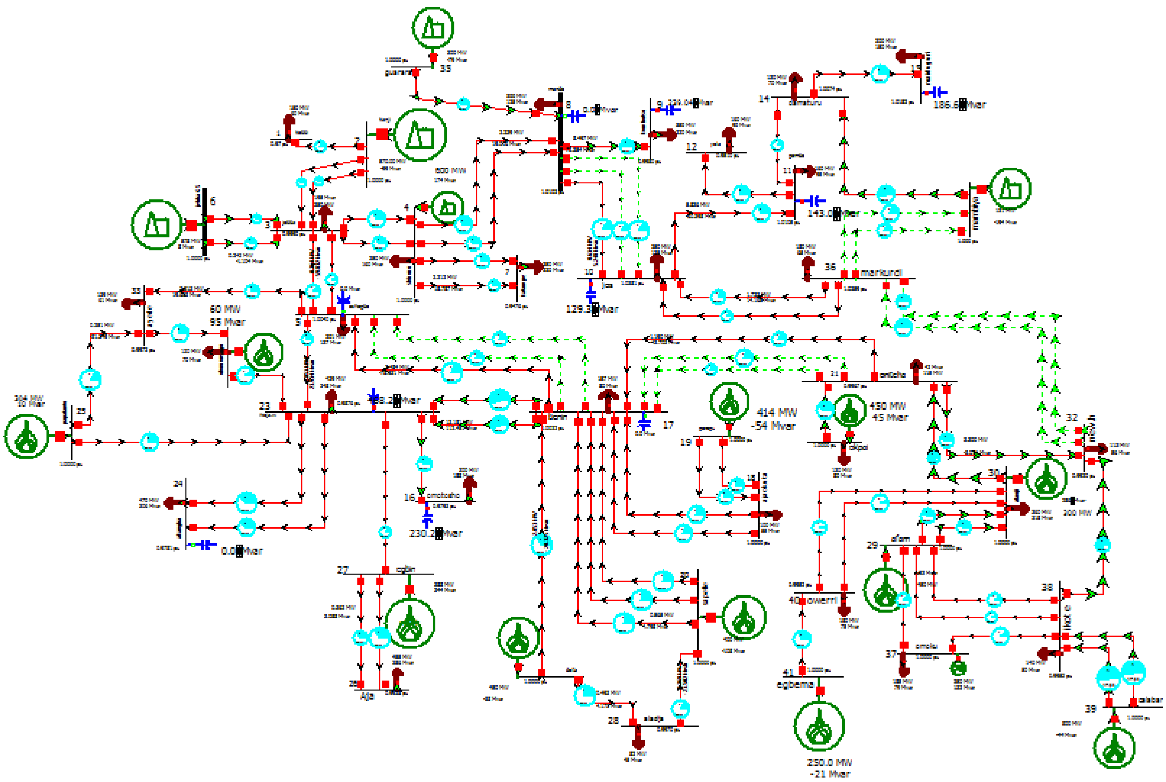

Fig. 2: Single line diagram of the base case for forty one bus model of Nigeria grid system

5.1 Base case data

Table 1.0: Voltage parameters for base case

Bus Records									
Number	Name	Nom kV	PU Volt	Volt (kV)	Load MW	Load Mar	Gen MW	Gen Mvar	Switched Shunts Mvar
1	Kebbi	330	0.97127	320.518	150	60			
2	Kanji	330	1	330			570	-99.33	
3	Jebba	330	0.99905	329.685	350	195			
4	Shiroro	330	1	330	250	160	600	174.04	
5	Oshogbo	330	1.00399	331.317	201	137			0
6	Jebba gs	330	1	0			578.4	8.42	
7	Katampe	330	0.95000	312.708	350	220			
8	Mando	330	1.01019	333.362	200	125			0
9	Kumbotso	330	0.99799	329.337	350	220			239.04
10	Jos	330	1.03809	342.569	250	125			129.32
11	Gombe	330	1.01049	333.463	160	95			142.95
12	Yola	330	0.95097	313.819	160	90			
13	Olunrunsogo	330	1	330	130	70	60	95.46	
14	Damaturu	330	1.0074	332.441	130	70			
15	Maiduguri	330	1.01822	336.014	200	150			186.62
16	Omotosho	330	0.9793	323.169	300	188			230.17
17	Benin	330	1.00222	330.734	157	80			0
18	Ajaokuta	330	1.00003	330.009	100	55			
19	Geregu	330	1	330			414	-53.73	
20	Sapelle	330	1	330			400	-108.45	
21	Onitcha	330	0.99666	328.898	115	42			
22	Delta	330	1	330			450	-37.99	
23	Ikeja.w	330	0.9876	325.906	429	248			468.17
24	Akangba	330	0.97814	322.788	470	306			0
25	Papalanto	330	1	330			304	9.6	
26	Aja	330	0.99279	327.622	455	286			
27	Egbin	330	1	330			388.24	343.5	
28	Aladja	330	0.99702	329.016	82	45			
29	Afam	330	1	330			450	-53.21	
30	Alaoji	330	1	330	360	218	300	285.79	
31	Okpai	330	1	330	130	80	450	45.11	

32	New.h	330	0.99204	327.373	113	56			
33	Ayede	330	0.99723	329.086	139	61			
34	Mambiya	330	1	330			130.88	-194.3	
35	Guarara	330	1	330			300	-79.43	
36	Markurdi	330	1.02588	338.54	180	65			
37	Omoku	330	1	330	185	79	250	131.85	
38	Ikot e	330	0.99526	328.435	139.81	50			
39	Calabar	330	1	330			800	-43.54	
40	Owerri	330	0.99519	328.412	180	75			
41	Egbema	330	1	330			250	-20.56	

Table 2.0: Line parameters for Base case

Line parameters								
Line Name (From – To)	Line Number	MW From	Mvar From	MVA From	Lim MVA	% MVA Limit (Max)	MW Loss	Mvar Loss
Kebbi - Kanji	01-02	-150	-60	161.6	773.4	20.9	2.69	-97.18
Kanji - Jebba	02-03	208.7	-31.1	211	777.3	27.1	1.26	-20.99
Jebba - Kanji	03-02	-207.4	10.1	207.6	777.3	27.1	1.26	-20.99
Shiroro - Jebba	04-03	-251.7	7.2	251.8	777.3	33.9	5.74	-47.45
Jebba - Shiroro	03-04	257.5	-54.6	263.2	777.3	33.9	5.74	-47.45
Jebba - Oshogbo	03-05	63.9	-47.7	79.7	777.3	10.3	0.26	-59.83
Jebba - Oshogbo	03-05	63.9	-47.7	79.7	777.3	10.3	0.26	-59.83
Jebba Gs - Jebba	06-03	289.2	4.2	289.2	777.3	37.2	0.24	-1.1
Jebba Gs - Jebba	06-03	289.2	4.2	289.2	777.3	37.2	0.24	-1.1
Shiroro - Katampe	04-07	177.2	73.6	191.9	777.4	26.6	2.21	-36.41
Shiroro - Katampe	04-07	177.2	73.6	191.9	777.4	26.6	2.21	-36.41
Shiroro - Mando	04-08	249.5	-73.7	260.2	777.3	33.5	2.24	-19.05
Shiroro -Mando	04-08	249.5	-73.7	260.2	777.3	33.5	2.24	-19.05
Oshogbo - Benin	05-17	-163.4	-18	164.4	777.3	22.7	2.48	-78.93
Oshogbo - Benin	05-17	-163.4	-18	164.4	777.3	22.7	2.48	-78.93
Oshogbo - Benin	05-17	-163.4	-18	164.4	777.3	22.7	2.48	-78.93
Oshogbo - Ikeja.W	05-23	178.1	-37.1	181.9	777.3	23.4	2.85	-74.71
Oshogbo - Ayede	05-33	238.5	-21.4	239.4	777.3	30.8	2.32	-25.54
Mando - Kumbotso	08-09	358.5	-22.1	359.2	777.3	46.2	8.5	-3.03
Mando - Jos	08-10	77.7	-94.1	122.1	777.3	15.7	0.66	-76.11
Mando - Jos	08-10	77.7	-94.1	122.1	777.3	15.7	0.66	-76.11
Mando - Jos	08-10	77.7	-94.1	122.1	777.3	15.7	0.66	-76.11
Guarara - Mando	35-08	300	-79.4	310.3	777.3	39.9	2.86	-9.47
Jos - Gombe	10-11	257.1	-25.6	258.4	777.3	33.2	5.84	-60.4

Jos - Markurdi	10-36	-137.9	-12	138.5	777.3	20.5	1.72	-89.2
Jos - Markurdi	10-36	-137.9	-12	138.5	777.3	20.5	1.72	-89.2
Yola - Gombe	12-11	-160	-90	183.6	777.3	23.6	2.89	-76.65
Damaturu - Gombe	14-11	71.7	-75.3	103.9	777.3	13.4	0.06	-5.93
Olunrunsogo - Ikeja.W	13-23	55.9	-0.1	55.9	777.3	9.5	0.17	-48.92
Ayede - Olunrunsogo	33-13	204.8	-43.8	209.5	777.3	26.9	78.95	-18.28
Damaturu - Maiduguri	14-15	201.8	-69.9	213.6	777.3	27.5	1.83	-33.27
Damaturu - Mambiya	14-34	-403.5	75.2	410.4	777.3	53.4	7.34	14.52
Ikeja.W - Omotosho	23-16	305.5	4.4	305.5	777.3	39.3	5.48	46.54
Ajaokuta - Benin	18-17	156.9	-53.1	165.7	777.3	21.3	1.74	-62.32
Benin - Ajaokuta	17-18	-155.2	-9.3	155.5	777.3	21.3	1.74	-62.32
Benin - Sapelle	17-20	-174.1	27.8	176.3	777.3	23.1	0.57	-14.86
Benin - Sapelle	17-20	-174.1	27.8	176.3	777.3	23.1	0.57	-14.86
Benin - Sapelle	17-20	-174.1	27.8	176.3	777.3	23.1	0.57	-14.86
Benin - Onitcha	17-21	-151.7	9.3	152	777.3	20.8	1.19	-43.7
Benin - Onitcha	17-21	-151.7	9.3	152	777.3	20.8	1.19	-43.7
Benin - Onitcha	17-21	-151.7	9.3	152	777.3	20.8	1.19	-43.7
Benin - Delta	17-22	-241.1	25.9	242.5	777.3	31.8	2.05	-20.32
Ikeja.W - Benin	23-17	-423.9	44.4	426.3	777.3	56.2	13.18	36.47
Ikeja.W - Benin	23-17	-423.9	44.4	426.3	777.3	56.2	13.18	36.47
Geregu - Ajaokuta	19-18	207	-26.9	208.7	777.3	26.9	0.08	-1.3
Geregu - Ajaokuta	19-18	207	-26.9	208.7	777.3	26.9	0.08	-1.3
Aladja - Sapelle	28-20	124.4	-40.9	130.9	777.3	16.8	0.37	-21.5
Onitcha - Alaoji	21-30	-597.3	115.5	608.4	777.3	79.2	18.61	104.59
Onitcha - Okpai	21-31	-315	23.8	315.9	777.3	41.4	5	-11.13
Onitcha - New.H	21-32	338.5	-22.3	339.2	777.3	43.6	3.3	-3.01
Delta - Aladja	22-28	206.9	8.3	207	777.3	26.6	0.49	4.17
Akangba - Ikeja.W	24-23	-235	-153	280.4	777.3	36.1	0.5	-2.25
Akangba - Ikeja.W	24-23	-235	-153	280.4	777.3	36.1	0.5	-2.25
Papalanto - Ikeja.W	25-23	196	17.9	196.9	777.3	25.3	1.67	14.13
Ikeja.W - Egbin	23-27	67.7	-84.3	108.2	777.3	13.9	0.22	-22.12
Ayede - Papalanto	33-25	-107.7	-13.1	108.5	777.3	14	0.25	-21.35
Egbin - Aja	27-26	227.9	140.6	267.8	777.3	34.6	0.36	-2.36
Egbin - Aja	27-26	227.9	140.6	267.8	777.3	34.6	0.36	-2.36
Alaoji - Afam	30-29	-304	35.2	306	777.3	39.5	0.54	-1.72
Alaoji - Afam	30-29	-304	35.2	306	777.3	39.5	0.54	-1.72
Afam - Omoku	29-37	-82.1	3.5	82.2	777.3	10.8	0.08	-12.25
Afam - Ikot E	29-38	-38.5	8.6	39.4	777.3	7.1	0.06	-30.74
Afam - Ikot E	29-38	-38.5	8.6	39.4	777.3	7.1	0.06	-30.74
Alaoji - Owerri	30-40	-34	4.1	34.2	777.3	6.6	0.05	-34.71
Alaoji - Owerri	30-40	-34	4.1	34.2	777.3	6.6	0.05	-34.71

Markurdi - New.H	36-32	-372.1	95	384	777.3	50.7	13.25	13.53
Markurdi - New.H	36-32	-372.1	95	384	777.3	50.7	13.25	13.53
New.H - Ikot E	32-38	-548.5	87.7	555.4	777.3	72	9.18	135.87
Markurdi - Mambiya	36-34	142.4	-50.3	151	777.3	20	2.44	-117.15
Markurdi - Mambiya	36-34	142.4	-50.3	151	777.3	20	2.44	-117.15
Omoku - Ikot E	37-38	-17.2	68.6	70.8	777.3	10.1	0.04	-8.21
Ikot E - Calabar	38-39	-395.9	28.6	396.9	777.3	51.5	4.11	6.87
Ikot E - Calabar	38-39	-395.9	28.6	396.9	777.3	51.5	4.11	6.87
Owerri - Egbema	40-41	-248	2.7	248	777.3	32.3	1.99	-17.88

6.0 Three generators contingency (outage)

CASE N-1 contingency analysis: When Egbema, Geregu and Shiroro generators are shut down, the state of generators are well represented in Fig 3. Generators with 0MW are out of service.

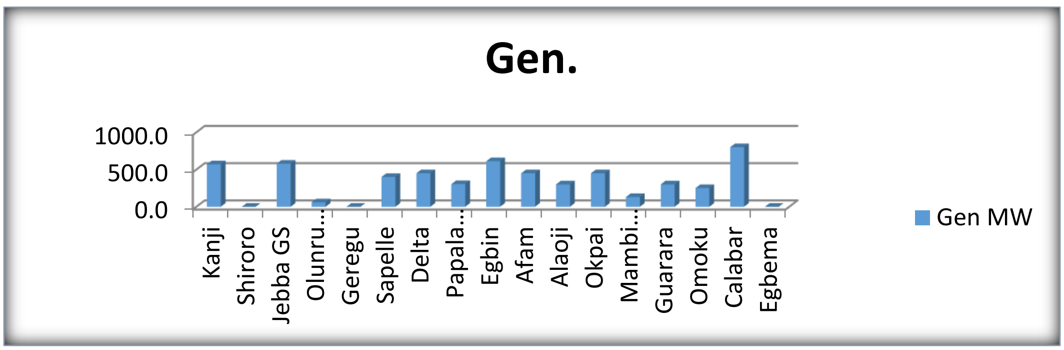

Fig. 3: Graphical representation of three generators outage.

Effect: Fig. 4, 5 and 6 are diagrams showing system behaviour when three generators are shutdown.

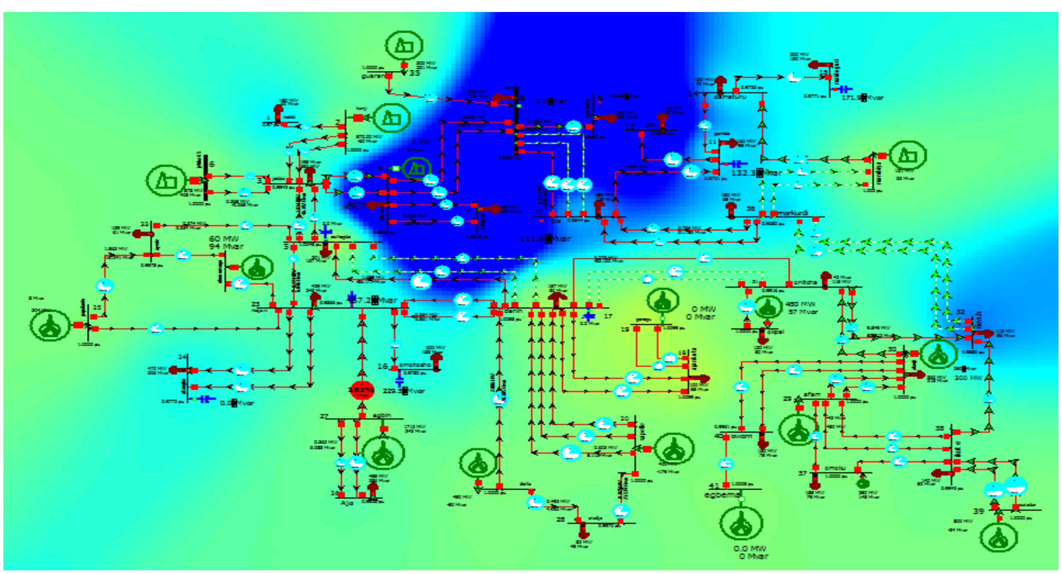

Fig. 4: Voltage contour display when Egbema, Geregu and Shiroro generators were shut down

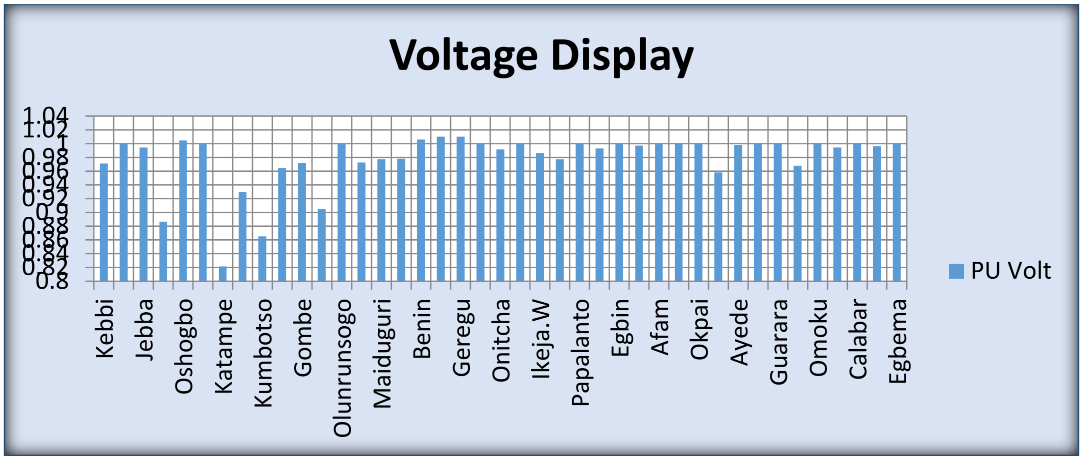

Fig. 5: Voltage graphical display when Egbema, Geregu and Shiroro generators were shut down

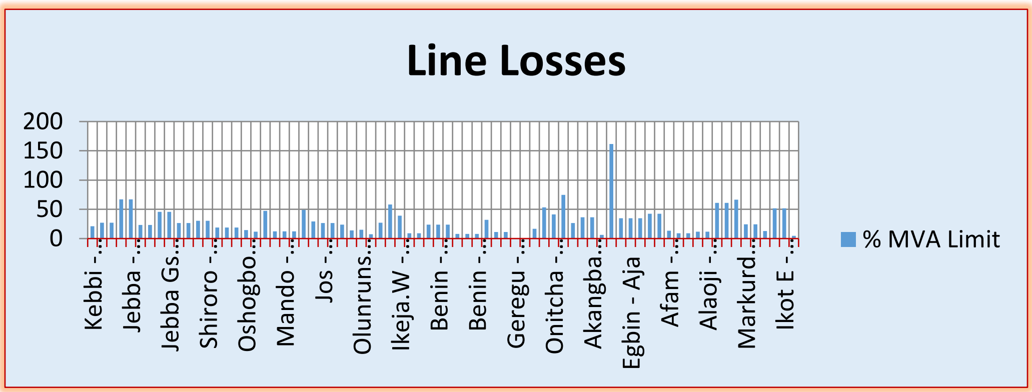

Fig.6: Line graphical display when Egbema, Geregu and Shiroro generators were shut down

Observation: When three generators were shutdown, Bus 4,7,8,9 and 12 voltage was violated with per unit value 0.8865, 0.82149, 0.92961, 0.86505 and 0.90487 respectively. This means that the affected bus voltage value have crossed the required voltage limit. Fig. 5 was plotted using during outage parameter in table 3.0.

Moreover, all line parameters are within its safe limit excluding line Ikeja west to Egbin with violated percentage MVA value of 162, this can be seen in table 4.0. Fig. 6 was plotted using during outage parameter in table 4.0.

6.1 Remedial Actions

Generator outage led to voltage and line MVA limit violation. Reactive power compensation which involve addition of shunt capacitor value 200MVar and 400MVar in bus 6 (Jebba) and bus 4 (Shiroro) respectively was done to clear voltage violation. Thus, double line circuit action between Ikeja West and Egbin ensured line violation clearance. Post correction data of table 3.0 and table 4.0 produced fig. 8 and 9 respectively. Fig. 7, 8 and 9 are diagrams showing system behaviour after these actions were taken.

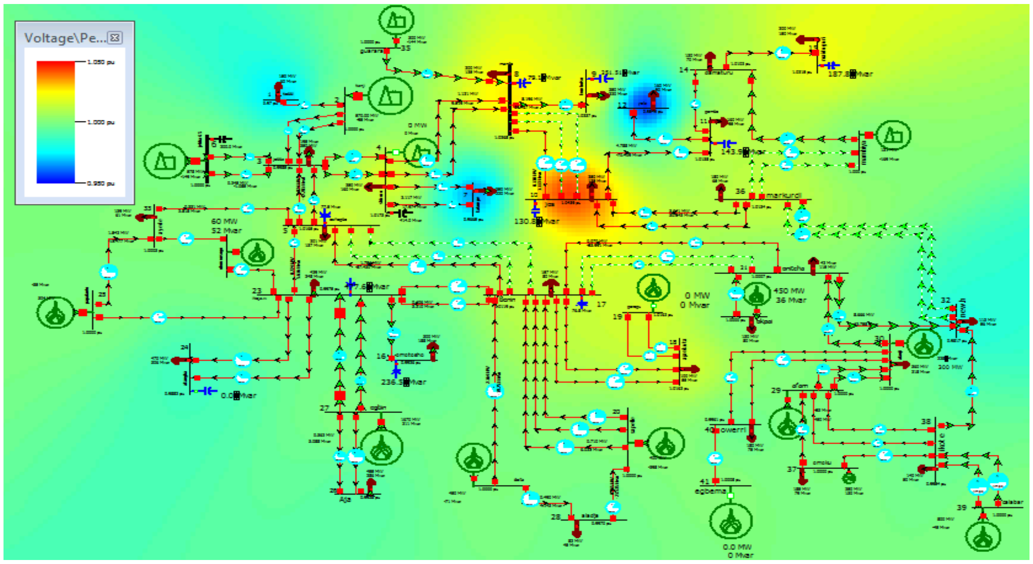

Fig. 7: Voltage contour display after corrective actions were taken

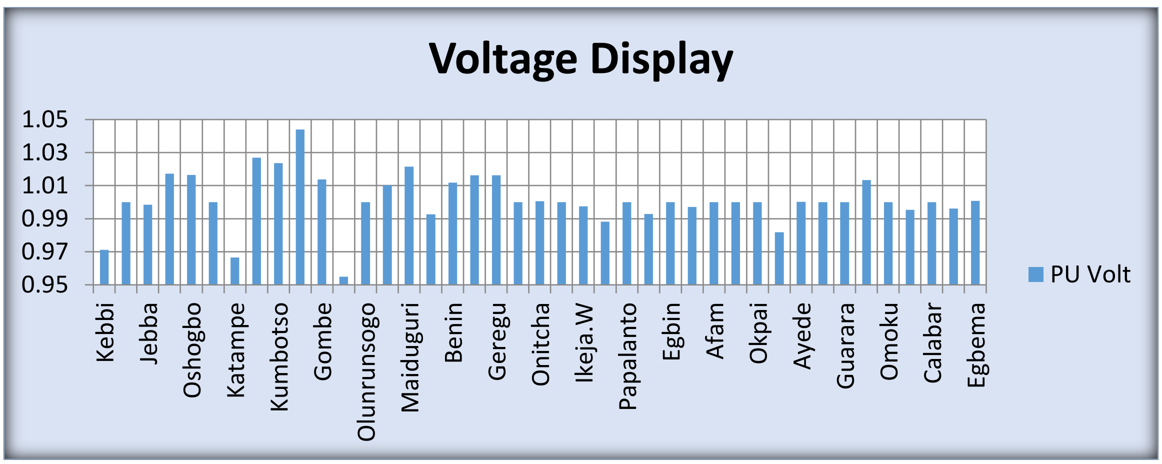

Fig. 8: Voltage graphical display after corrective actions were taken

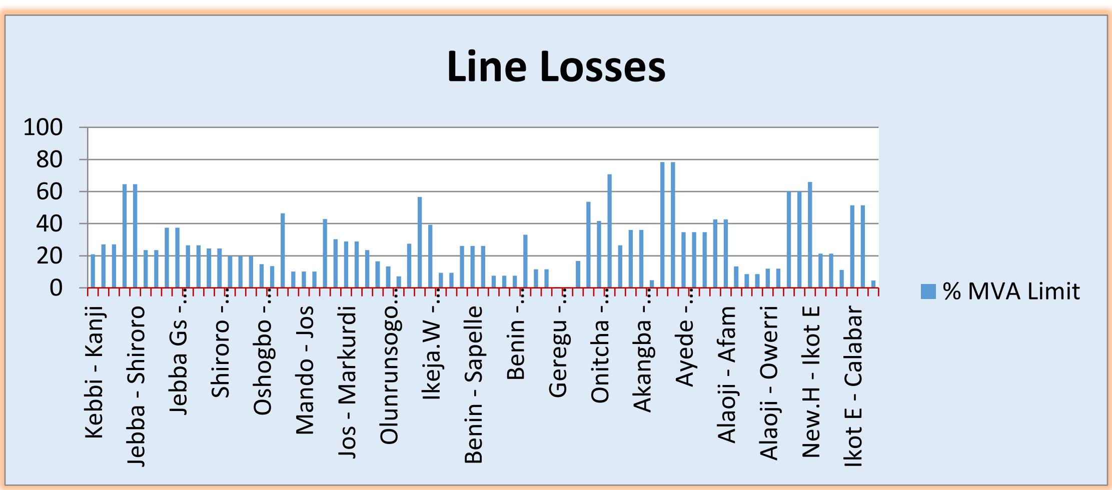

Fig. 9: Line graphical representation after corrective actions were taken

Bus record

Table 3.0: Voltage parameters data during generators outage and after remedial (post correction) action was taken

BUS		DURING OUTAGE			POST CORRECTION	
Number	Name	PU Volt	Volt (kV)	Nom kV	PU Volt	Volt (kV)
1	kebbi	0.97127	320.518	330	0.97127	320.518
2	kanji	1	330	330	1	330
3	jebba	0.99419	328.083	330	0.99852	329.513
4	shiroro	0.8865	292.543	330	1.01732	335.714
5	oshogbo	1.00475	331.568	330	1.01652	335.452
6	jebba GS	1	330	330	1	330
7	katampe	0.82149	271.092	330	0.96654	318.957
8	mando	0.92961	306.77	330	1.02685	338.86
9	kumbotso	0.86505	285.466	330	1.0237	337.821
10	jos	0.96438	318.247	330	1.04388	344.48
11	gombe	0.97211	320.795	330	1.0138	334.554
12	yola	0.90487	298.606	330	0.9549	315.117
13	olunrunsogo	1	330	330	1	330
14	damaturu	0.97227	320.85	330	1.01023	333.375
15	maiduguri	0.97711	322.446	330	1.02152	337.103
16	omotosho	0.97798	322.733	330	0.99262	327.566
17	benin	1.00582	331.921	330	1.01185	333.911
18	ajaokuta	1.00991	333.271	330	1.01622	335.353
19	geregu	1.00993	333.276	330	1.01624	335.358
20	sapelle	1	330	330	1	330
21	onitcha	0.99157	327.217	330	1.00067	330.222
22	delta	1	330	330	1	330
23	ikeja.w	0.98662	325.583	330	0.9975	329.176
24	akangba	0.97716	322.461	330	0.98815	326.09
25	papalanto	1	330	330	1	330
26	Aja	0.99279	327.622	330	0.99279	327.622
27	egbin	1	330	330	1	330
28	aladja	0.99702	329.016	330	0.99702	329.016
29	afam	1	330	330	1	330
30	alaoji	1	330	330	1	330
31	okpai	1	330	330	1	330
32	new.h	0.95797	316.132	330	0.98174	323.974
33	ayede	0.9978	329.275	330	1.00027	330.09
34	mambiya	1	330	330	1	330
35	guarara	1	330	330	1	330
36	markurdi	0.96796	319.428	330	1.01339	334.42
37	omoku	1	330	330	1	330

38	ikot e	0.99421	328.088	330	0.99537	328.473
39	calabar	1	330	330	1	330
40	owerri	0.99608	328.707	330	0.99608	328.707
41	egbema	1.0008	330.265	330	1.0008	330.265

Line Record

Table 4.0: Line parameters data during generators outage and after remedial (post correction) action was taken

LINE DATA	DURING OUTAGE				POST-CORRECTION DATA		
From - To	% of MVA Limit (Max)	MW Loss	Mvar Loss	Lim MVA	% of MVA Limit (Max)	MW Loss	Mvar Loss
Kebbi - Kanji	20.9	2.69	-97.18	773.4	20.9	2.69	-97.18
Kanji - Jebba	26.9	1.26	-20.89	777.3	27.1	1.26	-20.99
Jebba - Kanji	26.9	1.26	-20.89	777.3	27.1	1.26	-20.99
Shiroro - Jebba	66.8	24.7	126.35	777.3	64.6	21.53	86.61
Jebba - Shiroro	66.8	24.7	126.35	777.3	64.6	21.53	86.61
Jebba - Oshogbo	23.5	1.83	-46.19	777.3	23.6	1.82	-47.28
Jebba - Oshogbo	23.5	1.83	-46.19	777.3	23.6	1.82	-47.28
Jebba Gs - Jebba	45.5	0.36	-0.06	777.3	37.4	0.24	-1.08
Jebba Gs - Jebba	45.5	0.36	-0.06	777.3	37.4	0.24	-1.08
Shiroro - Katampe	26.6	3.03	-16.73	777.4	26.6	2.12	-39.29
Shiroro - Katampe	26.6	3.03	-16.73	777.4	26.6	2.12	-39.29
Shiroro - Mando	30.3	2.22	-12.21	777.3	24.5	1.12	-29.84
Shiroro -Mando	30.3	2.22	-12.21	777.3	24.5	1.12	-29.84
Oshogbo - Benin	19.1	1.69	-86.17	777.3	19.8	1.75	-87.43
Oshogbo - Benin	19.1	1.69	-86.17	777.3	19.8	1.75	-87.43
Oshogbo - Benin	19.1	1.69	-86.17	777.3	19.8	1.75	-87.43
Oshogbo - Ikeja.W	14.7	0.77	-92.56	777.3	14.7	0.72	-95.24
Oshogbo - Ayede	11.8	0.28	-42.93	777.3	13.5	0.34	-43.1
Mando - Kumbotso	47.4	11.02	33.71	777.3	46.4	8.2	-8.83
Mando - Jos	12.1	0.35	-66.9	777.3	10.2	0.17	-82.02
Mando - Jos	12.1	0.35	-66.9	777.3	10.2	0.17	-82.02
Mando - Jos	12.1	0.35	-66.9	777.3	10.2	0.17	-82.02
Guarara - Mando	48.7	4.6	7.95	777.3	42.8	3.23	-6.89
Jos - Gombe	29.2	4.84	-57.2	777.3	30.2	4.79	-70.41
Jos - Markurdi	26.6	3.76	-58.81	777.3	28.8	3.64	-72.07
Jos - Markurdi	26.6	3.76	-58.81	777.3	28.8	3.64	-72.07
Yola - Gombe	23.6	3.22	-65.28	777.3	23.6	2.86	-77.62
Damaturu - Gombe	14.2	0.07	-5.34	777.3	16.6	0.09	-5.69
Olunrunsogo - Ikeja.W	15.2	0.53	-45.82	777.3	13.3	0.43	-47.25
Ayede - Olunrunsogo	7.4	78.39	-23.44	777.3	7.1	78.58	-23.53

Damaturu - Maiduguri	26.8	1.9	-29.02	777.3	27.5	1.82	-33.61
Damaturu - Mambiya	58.1	8.91	29.52	777.3	56.6	8.23	21.95
Ikeja.W - Omotosho	39.3	5.5	46.64	777.3	39.3	5.37	45.58
Ajaokuta - Benin	9.2	0.21	-76.42	777.3	9.3	0.21	-77.39
Benin - Ajaokuta	9.2	0.21	-76.42	777.3	9.3	0.21	-77.39
Benin - Sapelle	24	0.6	-14.61	777.3	26.2	0.71	-13.82
Benin - Sapelle	24	0.6	-14.61	777.3	26.2	0.71	-13.82
Benin - Sapelle	24	0.6	-14.61	777.3	26.2	0.71	-13.82
Benin - Onitcha	8.1	0.08	-53.1	777.3	7.6	0.07	-53.99
Benin - Onitcha	8.1	0.08	-53.1	777.3	7.6	0.07	-53.99
Benin - Onitcha	8.1	0.08	-53.1	777.3	7.6	0.07	-53.99
Benin - Delta	32.2	2.09	-20.18	777.3	33	2.16	-19.75
Ikeja.W - Benin	11.4	0.36	-73.33	777.3	11.5	0.41	-74.27
Ikeja.W - Benin	11.4	0.36	-73.33	777.3	11.5	0.41	-74.27
Geregu - Ajaokuta	0.3	0	-2	777.3	0.3	0	-2.02
Geregu - Ajaokuta	0.3	0	-2	777.3	0.3	0	-2.02
Aladja - Sapelle	16.8	0.37	-21.51	777.3	16.8	0.36	-21.54
Onitcha - Alaoji	53.3	8.41	17.89	777.3	53.7	8.46	17.84
Onitcha - Okpai	41.3	5	-10.88	777.3	41.6	5.01	-11.24
Onitcha - New.H	74.5	9.85	53.81	777.3	70.7	8.67	42.76
Delta - Aladja	26.6	0.49	4.16	777.3	26.5	0.49	4.14
Akangba - Ikeja.W	36.1	0.5	-2.23	777.3	36.1	0.49	-2.46
Akangba - Ikeja.W	36.1	0.5	-2.23	777.3	36.1	0.49	-2.46
Papalanto - Ikeja.W	6.1	0.1	0.83	777.3	4.8	0.06	0.52
Ikeja.W - Egbin	161.8	35.17	274.32	777.3	78.3(2)	8.2 (2)	45.29(2)
Ayede - Papalanto	34.8	1.56	-10.24	777.3	34.6	1.54	-10.48
Egbin - Aja	34.6	0.36	-2.36	777.3	34.6	0.36	-2.36
Egbin - Aja	34.6	0.36	-2.36	777.3	34.6	0.36	-2.36
Alaoji - Afam	42.5	0.63	-0.99	777.3	42.6	0.63	-0.97
Alaoji - Afam	42.5	0.63	-0.99	777.3	42.6	0.63	-0.97
Afam - Omoku	13.3	0.12	-11.88	777.3	13.4	0.13	-11.88
Afam - Ikot E	8.9	0.1	-30.33	777.3	8.5	0.1	-30.42
Afam - Ikot E	8.9	0.1	-30.33	777.3	8.5	0.1	-30.42
Alaoji - Owerri	11.9	0.26	-32.95	777.3	11.9	0.26	-32.95
Alaoji - Owerri	11.9	0.26	-32.95	777.3	11.9	0.26	-32.95
Markurdi - New.H	61.2	21.5	93.35	777.3	60.2	19.48	69.34
Markurdi - New.H	61.2	21.5	93.35	777.3	60.2	19.48	69.34
New.H - Ikot E	66.7	7.98	111.36	777.3	65.9	7.71	103.48
Markurdi - Mambiya	24.5	3.6	-99.29	777.3	21.4	2.87	-111.73
Markurdi - Mambiya	24.5	3.6	-99.29	777.3	21.4	2.87	-111.73
Omoku - Ikot E	13.1	0.08	-7.93	777.3	11.1	0.05	-8.13

Ikot E - Calabar	51.5	4.11	6.89	777.3	51.5	4.11	6.87
Ikot E - Calabar	51.5	4.11	6.89	777.3	51.5	4.11	6.87
Owerri - Egbema	4.5	0.01	-34.74	777.3	4.5	0.01	-34.74

7.0 Results and Discussions

The bus labelled Egbim, which is the system slack bus generates active power of 657 MW and reactive power of 450.85 MVar. As such this indicates that the loads on the system require more power than is supplied by the generators and this deficit is taken care of by the slack bus. In the event that there is excess power in the system, the slack bus will in turn draw this power.

From bus contour diagrams, the coloured background shows the voltage difference among the system. The red means the highest voltage and blue means the lowest voltage. The simulation diagram is shown in Fig. 2.

Line power flow is said to be violated when the actual power flow post contingency exceeds the line flow limits which depend on the protection relay settings. Some contingencies lead to line flow violations, and some of them do not lead to any violations. The lines connecting the different buses have set thermal ratings. As the power requirements are adjusted, the flow of active and reactive power from and to the generators through the lines also changes. These changes are monitored by the pie charts that are indicated on each of the transmission lines in the system. The charts provide an elaborate warning scheme to guard against exceeding the line parameters.

8.0 Conclusion

This article analysed the probable contingencies on the Nigeria 330kv post reform integrated power system in order to explore uncertainties, effects of alternative internal and external changes in the power systems and to identify limitations that can affect the power reliability and security operations. It examined method for power system contingency study with techniques from available pattern that is recognised. The methods use the measured variables, such as bus admittance, busbar voltage, active and reactive power of generator, etc. to decide the state of the power system. This could make it easier to decide what needs to be done by the system operators to avoid blackout.

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