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Estimating Nigerian Power System Post Contingency Line Flows Using Power Distribution Factors

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ABSTRACT
At the point of convergence of any power system AC load flow iterative method, the principal bus parameters necessary to compute the transmission line flows and losses are provided. The exactness and accuracy of the result depends largely on the iterative method and the iteration termination criteria and each operating condition requires a unique solution of the analysis. State estimation techniques are also viable alternatives to AC load flow techniques in estimating network bus parameters from a known state but the speed of estimation is comparatively similar to the AC counterpart. However, the justification for the use of DC load flow for quick estimation of transmission line flows as against the AC is that the resulting mismatch is negligible when used for contingency and security analyses. Estimates of transmission line active power flow can be made using linear distribution/sensitivity factors whose result match those of DC load flow. These sensitivity factors: Power Transfer Distribution Factors (PTDF) and Line Outage Distribution Factors (LODF) are calculated and stored for a network and remains valid if the network remains significantly unmodified. With these stored factor from an operating point, post contingency flows may be predicted on any line. In this work, the PTDF and LODF of the Nigerian 330kV of 41 bus were computed and stored from a base case, then post contingency flows were predicted for the 77 transmission lines of the network following contingency in the form of 140MW load shedding at bus 1, 50% generator output reduction at bus 2, 100MW generator output increment at bus 20 and 100MW generator output decrease at bus 25. The result shows that using sensitivity factors to estimate transmission line flow works as validated by the result from load DC load flow technique. Therefore, a quicker, linear and non-iterative method is validated in order to estimate transmission line flows from a known operating point with the slack bus responsible for active power exchanges.

Keyword: *Distribution Factors; Post Contingency Flow; Line Outage; Generator Outage; Transmission Lines; Sensitivity Factors; Nigerian Network*

I. INTRODUCTION
For secure operation of interconnected power system components, safe operational limits are defined that must not be violated if continued reliable supply is to be sustained. Hence, meeting consumer electricity demand must not be attained at the expense of component safety nor the stability of the entire system. However, the inevitable changing operational conditions sometimes threaten to violate these safe limits. In other words, network complexity and condition of operation can result in system instability/collapse or at the very least forced component outages. It is instructive to note that not all component outage whether forced (as in the case of un-cleared faults) or scheduled (due to maintenance or repairs) lead to violations of prescribed limits on transmission lines or buses. But there are outages of certain components at certain operating condition that result in a significant alteration of the state of the entire power system. For instance, the outage a heavy loaded transmission line connected to a load center means significant widespread blackout at the load center leading to customer dissatisfaction. Then again, the sudden outage of a large generator may lead to undesired voltage profile containing violations across

a number of nodes which may culminate in voltage collapse. In other words, each components outage has a unique implication which is largely dependent on the component defined limits, its role and the condition of system operation. Therefore, a comprehensive knowledge of the network components and their condition of operation at the levels of design, planning and operation is indispensible for reliable supply and to this end, stability assessment methods are employed. One of such methods is sensitivity analysis which measures the sensitivity of a line component with respect to an outage or variation of flow on another transmission line or from generator at a node.

II. SENSITIVITY ANALYSIS

The word sensitivity is defined to be the degree of response of a system, to a change in the input signal. An extended definition with respect to power system network would mean that sensitivity analysis of power grid components is the process of determining the impact or effect on a particular system variable will cause and how it would vary from a known or desired state [1]. This enables the system planner or operator, to determine how the entire system would respond to a change and in this case an outage forced or scheduled. With respect to this, the pertinent questions are: is it possible to estimate a post-contingency power flow on transmission lines? Is it also possible to estimate power system defined limit violations and estimate the margin to violation from a current operational state following a viable grid component contingency? Such capability makes it possible to screen and select credible contingencies from a pool of possible contingencies, rank them on the bases of their severity and/or the number of violations they cause. This screening and ranking would enable remedial or preventive actions to be recommended or implemented to ameliorate the impact of such credible violation.

A. Distribution Factors

The problem of studying thousands of possible outages becomes herculean if the desire is to present quick results. However, one of the easiest ways to provide a quick calculation of possible overloads is to use linear sensitivity factors [2]. Since generators are the source of real power while transmission lines are the conveyors to the load centers, there is need to ascertain system sensitivities to the flows through these lines, especially when the output of the generator vary within network. Again since generator outputs and line flows of real power are summative, linear analysis involving direct current manipulations seem adequate especially for a lossless network. Linear sensitivity factors are preferred on the account of the ease and speed of calculation of possible overloads especially when studying numerous possible outages [3]. Power distribution factor is about the only technique used in allocating MW flows on the lines for power transaction in the system defines the relative change in the power flow on a particular line due to an injection or withdrawal of power on a pair of buses while line outage distribution factors are linear estimates of the change in flow on adjacent lines with the outage of transmission lines. Basically, they are of two types;

1. Power Transfer Distribution Factors (PTDF)

PTDF shows linearized impact of power transfer [4]. It is the relative change in power flow on a particular line due to an injection and withdrawal of power on a pair of buses [5]. They represent the sensitivity of the flow on line l to a shift of power from bus i to bus k [2]. Power Transfer Distribution Factors are also known by other names such as Generation Shift Factors (GSFs), Power Distribution Coefficients (PDCs), Effectiveness Factors and Impedance Factors. The PTDF has four (4) attributes, namely;

- a particular Line (with reference direction)
- a particular Bus
- value of the transfer factor
- a reference bus

The value of the PTDF of line l with respect to bus i is defined to be the change (or sensitivity) of active megawatt (MW) power flow in a reference direction on line l with respect to a change in injection at bus i and a corresponding change in withdrawal at the reference bus [6]. PTDF has the following mathematical expression as [7]

$$PTDF_{i,k,l} = \frac{\Delta f_l}{\Delta P_{i\ to\ k}} \qquad (1)$$

$PTDF_{i,k,l}$ = PTDF for power transfer from bus i to bus k

Δf_l = change in line flow of the monitored line when power is transferred

$\Delta P_{i\ to\ k}$ = power transferred from bus i to bus k

Numerical range of PTDF includes:
$-1 \leq PTDF_{i,k,l} \leq +1$

$PTDF_{i,k,l} = 1$, this is an indication that all of the transferred power from i to k must flow through line l. If the value is -1, it means that all of the transferred power from i to k will flow through line l, but in a reversed direction and if $PTDF_{i,k,l} = 0$, this indicates that none of the power transferred from i to k will pass through line l [8].

2. Line Outage Distribution Factor (LODF)

Line outage distribution factors are linear estimates of the change in flow on adjacent lines when transmission lines are lost [9]. They are often applied in checking overloads on the lines following the line loss [10]. The failure/outage of a major transmission line causes redistribution in the line flows and can result in voltage variation within the system. The analysis of transmission line failures requires methods to predict these line flows and voltages.

LODF shows linearized impact of power transfer. They represent the sensitivity of the flow on line l to a line failure in the network [2]. LODFs aids in calculating the impact the opening (outage) of a transmission line will have on all the other lines in the power system. The value of the LODF of line l with respect to loss of line t is defined to be the change (or sensitivity) of active (MW) power flow on line l with line t out.

A simulation program was used to study the cases of line outages in the system using the line outage distribution factors [11]. Outages of lines which cause increased power flow over prescribed limit in the remaining lines of the network are detected. The LODF factors are given as [7];

$$LODF_{l,t} = \frac{\Delta f_l}{f_t^0} \qquad (2)$$

$LODF_{l,t}$= line outage distribution factor when monitoring line l after an outage on line t

Δf_l= change in MW flow on monitored line l

f_t^0= original flow on outage (open) line t

III. METHODOLOGY

The aim of this work is to estimate post-contingency on the Nigerian 330kV transmission line flows using direct current based sensitivity factors. This would be achieved by

1. Estimating the power flow sensitivity of network transmission lines due to generators outages/output variation.
2. Estimating the power flow sensitivity of network transmission lines due to the outage of adjacent transmission lines.
3. Estimating post-outage transmission line active power flows
4. Verifying the post-contingency Active power flows estimated from sensitivity factors using post-contingency DC load-flow results.

The network used for this estimation is the Nigerian 330KV power system network consisting of 41 buses, 17 generators and 77 transmission lines. The network generator/bus data and line parameters are given in the appendix section.

A. Procedure:

1. Derive relationships for AC and DC load flows
2. Estimate the Transmission line flows for AC and DC methods for the network at a base case.
3. Following any contingency; transmission line outage, reduction/increase or total outage of generation at any generator (beside the Slack bus), estimate the DC line flows for all the transmission lines of the network.
4. Derive the equations representing the sensitivity factors; PTDF and LODF and for the network, evaluate the values of PTDF and LODF.
5. Using PTDF and LODF values, estimate transmission flow for a monitored line with respect to generation reduction, increase or outage and line outage.
6. For a monitored line, compare the estimated flow of (v) to the flows of (iii) above.

Executable MATLAB programs have been used to perform the AC load flow (Newton Raphson iteration), DC load flow, PTDF and LODF estimations.

Predicting Post contingency flow using

B. Mathematical Descriptions

Direct Current (DC) Load Flow of Sample Network

Unlike the AC load flow, the DC power flow is a non-iterative as it simplifies the Fast decoupled AC derivations under certain assumptions. Following these assumptions, the predominant relationship from the Fast decoupled method [12] relates ΔP and $\Delta\delta$, expressed as

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \vdots \\ \Delta P_{(n-1)} \end{bmatrix} = [B'] \begin{bmatrix} \Delta \delta_1 \\ \Delta \delta_2 \\ \vdots \\ \Delta \delta_{(n-1)} \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} \frac{\Delta P_1}{|V_1|} \\ \frac{\Delta P_2}{|V_2|} \\ \vdots \\ \frac{\Delta P_{(n-1)}}{|V_{(n-1)}|} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1(n-1)} \\ B_{21} & B_{22} & \cdots & B_{2(n-1)} \\ \vdots & \vdots & \vdots & \vdots \\ B_{(n-1)1} & B_{(n-1)2} & \cdots & B_{(n-1)(n-1)} \end{bmatrix} \begin{bmatrix} \Delta \delta_1 \\ \Delta \delta_2 \\ \vdots \\ \Delta \delta_{(n-1)} \end{bmatrix} \quad (4)$$

Where the diagonal and off diagonal of the reactance matrix B is

$B_{ii} = \sum_{k=1}^{N_{bus}} \frac{1}{x_{ik}}$ and $B_{ik} = B_{ki} = -\frac{1}{x_{ik}}$

But where r, the resistance of the transmission line is significant, then

$B_{ii} = \sum_{k=1}^{N_{bus}} -B_{ik}$ and $B_{ik} = B_{ki} = -\frac{x_{ik}}{r_{ik}^2 + x_{ik}^2}$

The DC load flow is adequate in estimating approximately accurate MW flows on transformers and transmission lines while ignoring the MVAR and MVA flows. Consequently, form [2], the real or MW power flow on a lossless transmission line connected between bus i and bus k using DC power flow is

$$P_{ik} = \frac{1}{x_{ik}} (\delta_i - \delta_k) \quad (5)$$

$i \; and \; k \; represent \; bus \; numbers \; (1,2,3,4, \dots, n)$

Note that $P_{ik} = -P_{ki}$

Then the Power scheduled at $bus \; i$, P_i is derived using

$$P_i = \sum_{k=1}^{l} P_{ik} \quad (6)$$

x_{ik} = reactance of line between bus i and bus k

P_i =Calculated Real power schedule at bus i and k respectively

P_{ik}= Real power flowing through transmission line connected between bus i and bus k

δ_i & δ_k= Voltage bus angle at bus i and k respectively

The power network used here is the Nigerian 330kV interconnected network. This version of the network contains 41 buses, 17 generators and 30 load units which are interconnected by 77 transmission lines. The total system base load is 7491 MW and the generator at bus 27 (Egbin) is used as slack/reference generator. The network oneline diagram is shown below while its network data with respect to bus, generator and line parameters are given in appendix tables 4.13, 4.14 and 4.15 respectively). In order to justify the choice of the DC over the AC flow estimation, we compare the AC and DC MW flows of the network at base case; noting how marginal the mismatch is.

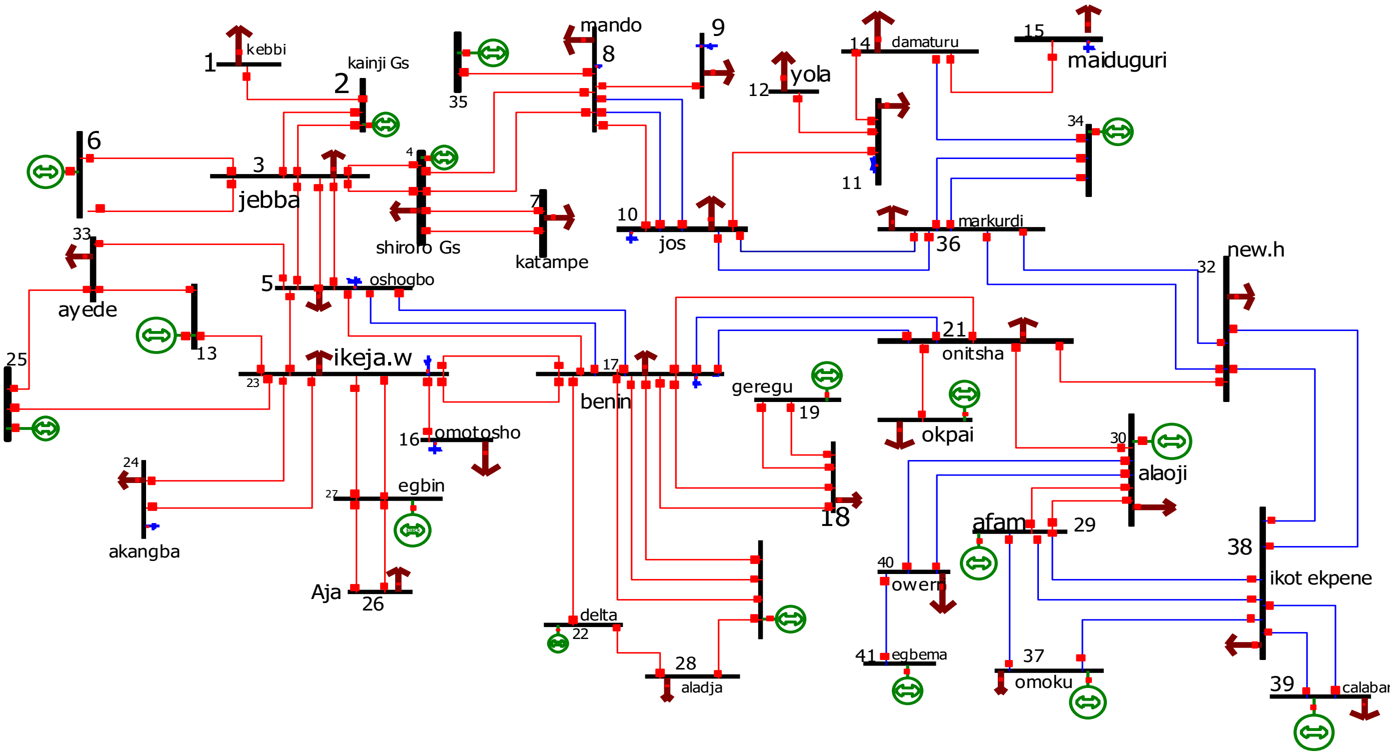

Figure 1: The Nigerian 330kV 41 bus system

Table 1: Base Case MW Flow Mismatch from AC and DC Load Flow Analysis

Line	Bus	Line MW flow		Mismatch		Line	Bus	Line MW flow		Mismatch	
Code	From-To	AC	DC	Actual	%	Code	From-To	AC	DC	Actual	%
L1	1-2	-150	-150	0	0.00	L40	18-17	146.93	147	0.07	0.05
L2	2-3	223.76	225	1.24	0.55	L41	19-18	197	197	0	0.00
L3	2-3	223.76	225	1.24	0.55	L42	19-18	197	197	0	0.00
L4	3-4	476.38	437.91	38.47	8.08	L43	21-30	74.23	57	17.23	23.21
L5	3-4	476.38	437.91	38.47	8.08	L44	21-31	-315.32	-320	4.68	1.48
L6	3-5	-119.92	-91.94	27.98	23.33	L45	21-32	552.04	504.11	47.93	8.68
L7	3-5	-119.92	-91.94	27.98	23.33	L46	22-28	370.28	371.62	1.34	0.36
L8	3-5	-119.92	-91.94	27.98	23.33	L47	23-16	305.5	300	5.5	1.80
L9	6-3	250	250	0	0.00	L48	23-17	-224.26	-281.98	57.72	25.74
L10	6-3	250	250	0	0.00	L49	23-17	-224.26	-281.98	57.72	25.74
L11	4-7	177.04	175	2.04	1.15	L50	23-27	-277.23	-176.06	101.17	36.49
L12	4-7	177.04	175	2.04	1.15	L51	23-27	-277.23	-176.06	101.17	36.49
L13	4-8	293.88	275.41	18.47	6.28	L52	24-23	-235	-235	0	0.00

L14	4-8	293.88	275.41	18.47	6.28	L53	24-23	-235	-235	0	0.00
L15	5-17	-178.22	-174.91	3.31	1.86	L54	25-23	72.32	95.16	22.84	31.58
L16	5-17	-178.22	-174.91	3.31	1.86	L55	27-26	227.86	227.5	0.36	0.16
L17	5-17	-178.22	-174.91	3.31	1.86	L56	27-26	227.86	227.5	0.36	0.16
L18	5-23	11.61	45.06	33.45	288.11	L57	28-20	66.7	69.62	2.92	4.38
L19	5-33	-40.25	2.86	43.11	107.11	L58	29-37	210.34	201.74	8.6	4.09
L20	8-9	357.95	350	7.95	2.22	L59	29-38	127.48	123.72	3.76	2.95
L21	8-10	73.9	66.94	6.96	9.42	L60	29-38	127.48	123.72	3.76	2.95
L22	8-10	73.9	66.94	6.96	9.42	L61	30-29	7.65	-0.41	8.06	105.36
L23	8-10	73.9	66.94	6.96	9.42	L62	30-29	7.65	-0.41	8.06	105.36
L24	10-11	288.68	269.38	19.3	6.69	L63	30-40	49.3	49	0.3	0.61
L25	10-36	-159.34	-159.28	0.06	0.04	L64	30-40	49.3	49	0.3	0.61
L26	10-36	-159.34	-159.28	0.06	0.04	L65	32-38	-285.84	-282.09	3.75	1.31
L27	12-11	-160	-160	0	0.00	L66	32-38	-285.84	-282.09	3.75	1.31
L28	13-23	120.69	142.7	22.01	18.24	L67	33-13	-148.85	-127.3	21.55	14.48
L29	14-11	40.49	50.62	10.13	25.02	L68	33-25	-31.38	-8.84	22.54	71.83
L30	14-15	201.83	200	1.83	0.91	L69	35-8	200	200	0	0.00
L31	14-34	-372.32	-380.62	8.3	2.23	L70	36-32	-444.33	-439.15	5.18	1.17
L32	17-18	-145.35	-147	1.65	1.14	L71	36-32	-444.33	-439.15	5.18	1.17
L33	17-20	-320.01	-323.21	3.2	1.00	L72	36-34	192.76	189.87	2.89	1.50
L34	17-20	-320.01	-323.21	3.2	1.00	L73	36-34	192.76	189.87	2.89	1.50
L35	17-20	-320.01	-323.21	3.2	1.00	L74	37-38	154.24	146.74	7.5	4.83
L36	17-21	142.96	118.77	24.19	16.92	L75	38-39	-154.31	-155	0.69	0.45
L37	17-21	142.96	118.77	24.19	16.92	L76	38-39	-154.31	-155	0.69	0.45
L38	17-21	142.96	118.77	24.19	16.92	L77	40-41	-81.6	-82	0.4	0.49
L39	17-22	-335.56	-338.38	2.82	0.84						

VI. RESULT AND DISCUSSION

A. Evaluating PTDF and LODF

The process began by defining an operating point (also called the Base Case: BC) of the network. Subsequently, the DC MW flow and the linear sensitivity factors from this operating point (BC) are evaluated and stored. Table 1 gives the DC line flows for all 77 transmission line at the defined base case. The PTDF of 40 buses with respect to the slack bus (bus 27) while LODF of the 77 transmission lines can be calculated at this operating condition. The size of the resulting PTDF and LODF matrices cannot be reflected in this publication being 17 by 77 and 77 by 77 respectively. However, evaluating PTDF and LODF can be demonstrated. To this end, as table 2 shows, buses 2 and line 8 were chosen to demonstrate how PTDF and LODF of the 77 transmission lines are calculated. Using equation 1, restated as

$$PTDF_{i,k,l} = \frac{\Delta f_l}{\Delta P} = \frac{\widehat{f_l} - f_l^0}{\Delta P_{i\ to\ k}} \qquad (7)$$

f_l^0 & $\widehat{f_l}$: Pre and Post generator outage MW flow on line l $(l = 1, 2, \dots 77)$

$\Delta f_l = \widehat{f_l} - f_l^0$: Change in MW flow of the monitored line when power is transferred

$\Delta P_{i\ to\ k}$: Power transferred from Outage bus $i = 2$ to the Reference bus $k = 27$

Considering generator at bus 2, its pre-outage output is 600MW, the post outage output is 0MW. $\Delta P_{2\ to\ 27} = 0 - 600 = -600$MW. This is the power which the reference bus 27 now delivers at post-outage. If we were to monitor line $l = 4$, then from table 1, the pre-outage flow

$f_4^0 = 437.9MW$, post-outage flow $\widehat{f_4} = 400.3MW$

$$PTDF_{2,27,4} = \frac{\widehat{f_4} - f_4^0}{\Delta P_{2\ to\ 27}} = \frac{400.3 - 437.9}{-600} = 0.062667$$

Similarly,

$$LODF_{l,t} = \frac{\Delta f_l}{f_t^0} = \frac{\widehat{f_l} - f_l^0}{f_t^0} \qquad (8)$$

f_l^0 & $\widehat{f_l}$: Pre and Post outage MW flow on line l $(l = 1, 2, \dots 77)$

$\Delta f_l = \widehat{f_l} - f_l^0$: Change in MW flow on monitored line l

f_t^0= original flow on outage (open) line t

From Table 1, consider line $t = 8$, the pre-outage MW flow is -91.94MW (but actually flowing from bus 5 to bus 3). If we monitor line $l = 4$, its pre-outage flow $f_4^0 = 437.9MW$, and following the outage of line $t = 8$, the post outage flow on line $l = 4$; $\widehat{f_4} = 432.8MW$. Then,

$$LODF_{4,8} = \frac{\widehat{f_4} - f_4^0}{f_8^0} = \frac{432.8 - 437.9}{-91.94} = 0.005547$$

The complete PTDF and LODF for the 77 lines with respect to bus 2 and line 8 is given in table 2.

B. Predicting Post Contingency MW Flow from Sensitivity Factors

When contingency occurs in terms of line outage or generator/load outage, generator output/load variation then the evaluated and stored base case MW line flows and the sensitivity factors may be used to predict the line MW flow without resorting to the tedious load flow or state estimation techniques. Using PTDF, the MW line flow following power variation at any bus compensated by the reference bus k is

$$\widehat{f_l} = PTDF_{i,k,l} * \Delta P_{i\ to\ k} + f_l^0 \qquad (9)$$

While the MW line flow following line outage using LODF is

$$\widehat{f_l} = LODF_{l,t} * f_t^0 + f_l^0 \qquad (10)$$

Consider the following contingency conditions in table 4. Additionally, table 3 reports the PTDF with respect to buses 20 and 25 as well as the LODF with respect to lines 10, 15 and 49.

Table 2: Calculating PTDF and LODF for Bus 2 and Line 8

Line Code	Base Case flow	Gen2 Outage Flow	PTDF	L8 Outage Flow	LODF		Line Code	Base Case flow	Gen2 Outage Flow	PTDF	L8 Outage Flow	LODF
L1	-150.0	-150.0	0	-150.0	0		L40	147.0	147.0	0	147.0	0
L2	225.0	-75.0	0.5	225.0	0		L41	197.0	197.0	0	197.0	0
L3	225.0	-75.0	0.5	225.0	0		L42	197.0	197.0	0	197.0	0
L4	437.9	400.3	0.063	432.8	0.056		L43	57.2	78.0	-0.035	60.0	-0.031
L5	437.9	400.3	0.063	432.8	0.056		L44	-320.0	-320.0	0	-320.0	0
L6	-91.9	-266.9	0.292	-132.8	0.444		L45	504.1	558.5	-0.091	511.6	-0.081
L7	-91.9	-266.9	0.292	-132.8	0.444		L46	371.6	371.6	0	371.6	0
L8	-91.9	-266.9	0.292	0.0	-1		L47	300.0	300.0	0	300.0	0
L9	250.0	250.0	0	250.0	0		L48	-282.0	-155.4	-0.211	-280.5	-0.016
L10	250.0	250.0	0	250.0	0		L49	-282.0	-155.4	-0.211	-280.5	-0.016
L11	175.0	175.0	0	175.0	0		L50	-176.1	-476.1	0.5	-176.1	0
L12	175.0	175.0	0	175.0	0		L51	-176.1	-476.1	0.5	-176.1	0
L13	275.4	237.8	0.063	270.3	0.056		L52	-235.0	-235.0	0	-235.0	0
L14	275.4	237.8	0.063	270.3	0.056		L53	-235.0	-235.0	0	-235.0	0
L15	-174.9	-234.2	0.099	-172.5	-0.027		L54	95.2	-2.0	0.162	96.0	-0.009
L16	-174.9	-234.2	0.099	-172.5	-0.027		L55	227.5	227.5	0	227.5	0
L17	-174.9	-234.2	0.099	-172.5	-0.027		L56	227.5	227.5	0	227.5	0
L18	45.1	-112.4	0.263	46.4	-0.014		L57	69.6	69.6	0	69.6	0
L19	2.9	-186.5	0.316	4.5	-0.017		L58	201.7	210.5	-0.015	202.9	-0.013
L20	350.0	350.0	0	350.0	0		L59	123.7	129.8	-0.01	124.6	-0.009

L21	66.9	41.9	0.042	63.5	0.037		L60	123.7	129.8	-0.01	124.6	-0.009
L22	66.9	41.9	0.042	63.5	0.037		L61	-0.4	10.0	-0.017	1.0	-0.016
L23	66.9	41.9	0.042	63.5	0.037		L62	-0.4	10.0	-0.017	1.0	-0.016
L24	269.4	256.0	0.022	267.6	0.02		L63	49.0	49.0	0	49.0	0
L25	-159.3	-190.2	0.052	-163.5	0.046		L64	49.0	49.0	0	49.0	0
L26	-159.3	-190.2	0.052	-163.5	0.046		L65	-282.1	-292.5	0.017	-283.5	0.016
L27	-160.0	-160.0	0	-160.0	0		L66	-282.1	-292.5	0.017	-283.5	0.016
L28	142.7	50.5	0.154	143.5	-0.008		L67	-127.3	-219.6	0.154	-126.5	-0.008
L29	50.6	64.0	-0.022	52.5	-0.02		L68	-8.8	-106.0	0.162	-8.0	-0.009
L30	200.0	200.0	0	200.0	0		L69	200.0	200.0	0	200.0	0
L31	-380.6	-394.0	0.022	-382.5	0.02		L70	-439.2	-476.7	0.063	-444.3	0.056
L32	-147.0	-147.0	0	-147.0	0		L71	-439.2	-476.7	0.063	-444.3	0.056
L33	-323.2	-323.2	0	-323.2	0		L72	189.9	196.6	-0.011	190.8	-0.01
L34	-323.2	-323.2	0	-323.2	0		L73	189.9	196.6	-0.011	190.8	-0.01
L35	-323.2	-323.2	0	-323.2	0		L74	146.7	155.5	-0.015	147.9	-0.013
L36	118.8	143.8	-0.042	122.2	-0.037		L75	-155.0	-155.0	0	-155.0	0
L37	118.8	143.8	-0.042	122.2	-0.037		L76	-155.0	-155.0	0	-155.0	0
L38	118.8	143.8	-0.042	122.2	-0.037		L77	-82.0	-82.0	0	-82.0	0
L39	-338.4	-338.4	0	-338.4	0							

Table 3: Selected PTDF (Buses 20 & 25) and LODF (Line 10.15 & 49)

LC	Bus 20	Bus 25	L10	L15	L49	LC	Bus 20	Bus 25	L10	L15	L49
L1	0	0	0	0	0	**L40**	0	0	0	0	0
L2	0	0	0	0	0	**L41**	0	0	0	0	0
L3	0	0	0	0	0	**L42**	0	0	0	0	0
L4	-0.0204	0.0071	0	0.0565	0.0304	**L43**	0.0113	-0.0039	0	-0.0313	-0.0168
L5	-0.0204	0.0071	0	0.0565	0.0304	**L44**	0	0	0	0	0
L6	0.0136	-0.0047	0	-0.0377	-0.0202	**L45**	0.0295	-0.0102	0	-0.0817	-0.0439
L7	0.0136	-0.0047	0	-0.0377	-0.0202	**L46**	-0.0803	0	0	0	0
L8	0.0136	-0.0047	0	-0.0377	-0.0202	**L47**	0	0	0	0	0
L9	0	0	1	0	0	**L48**	-0.3288	-0.0595	0	0.1647	0.4898
L10	0	0	-1	0	0	**L49**	-0.3288	-0.0595	0	0.1647	-1
L11	0	0	0	0	0	**L50**	0.5	0.5	0	0	0
L12	0	0	0	0	0	**L51**	0.5	0.5	0	0	0
L13	-0.0204	0.0071	0	0.0565	0.0304	**L52**	0	0	0	0	0
L14	-0.0204	0.0071	0	0.0565	0.0304	**L53**	0	0	0	0	0
L15	-0.1006	0.0349	0	-1	0.1498	**L54**	0.0959	0.5726	0	0.0923	-0.1429
L16	-0.1006	0.0349	0	0.2788	0.1498	**L55**	0	0	0	0	0
L17	-0.1006	0.0349	0	0.2788	0.1498	**L56**	0	0	0	0	0
L18	0.1555	0.081	0	0.1496	-0.2317	**L57**	-0.0803	0	0	0	0
L19	0.187	-0.1999	0	0.1799	-0.2786	**L58**	0.0048	-0.0016	0	-0.0132	-0.0071
L20	0	0	0	0	0	**L59**	0.0033	-0.0011	0	-0.0091	-0.0049
L21	-0.0136	0.0047	0	0.0377	0.0202	**L60**	0.0033	-0.0011	0	-0.0091	-0.0049
L22	-0.0136	0.0047	0	0.0377	0.0202	**L61**	0.0056	-0.002	0	-0.0157	-0.0084
L23	-0.0136	0.0047	0	0.0377	0.0202	**L62**	0.0056	-0.002	0	-0.0157	-0.0084
L24	-0.0072	0.0025	0	0.0201	0.0108	**L63**	0	0	0	0	0
L25	-0.0168	0.0058	0	0.0465	0.025	**L64**	0	0	0	0	0
L26	-0.0168	0.0058	0	0.0465	0.025	**L65**	-0.0056	0.002	0	0.0157	0.0084

L27	0	0	0	0	0	**L66**	-0.0056	0.002	0	0.0157	0.0084
L28	0.0911	0.2274	0	0.0876	-0.1357	**L67**	0.0911	0.2274	0	0.0876	-0.1357
L29	0.0072	-0.0025	0	-0.0201	-0.0108	**L68**	0.0959	-0.4274	0	0.0923	-0.1429
L30	0	0	0	0	0	**L69**	0	0	0	0	0
L31	-0.0072	0.0025	0	0.0201	0.0108	**L70**	-0.0204	0.0071	0	0.0565	0.0304
L32	0	0	0	0	0	**L71**	-0.0204	0.0071	0	0.0565	0.0304
L33	-0.3066	0	0	0	0	**L72**	0.0036	-0.0013	0	-0.01	-0.0054
L34	-0.3066	0	0	0	0	**L73**	0.0036	-0.0013	0	-0.01	-0.0054
L35	-0.3066	0	0	0	0	**L74**	0.0048	-0.0016	0	-0.0132	-0.0071
L36	0.0136	-0.0047	0	-0.0377	-0.0202	**L75**	0	0	0	0	0
L37	0.0136	-0.0047	0	-0.0377	-0.0202	**L76**	0	0	0	0	0
L38	0.0136	-0.0047	0	-0.0377	-0.0202	**L77**	0	0	0	0	0
L39	-0.0803	0	0	0	0						

Table 4: Contingency definition for Post Contingency Flow Prediction

Contingency		MW Output		Exchanged	Slack bus
Definition	**Location**	**Pre-contingency**	**Post-Contingency**	**Power**	**action**
50% output Reduction	Bus 2	600	300	-300	supply more
100MW output Increment	Bus 20	900	1000	100	supply less
100MW output Reduction	Bus 25	304	204	-100	supply more
140 MW Load Reduction	Bus 1	150	10	140*	supply less

*The change with respect to load is positive, unlike generator.

From the base case and proceed with these mutually exclusive contingencies. Let's assume that the load center at bus 1 reduced its demand from the base case of 150MW to 10MW or that the outputs at generator buses 2, 20 and 25 were varied as stated on the table; the idea is to predict the MW flow on any or all of the transmission lines without resort to state estimation or load flow. In order to accomplish this, we need information of the flow at any operation and the corresponding linear sensitivity factors.

If we decide to predict the flows on line 54, when any of the contingencies of table 4 occur, then we would need the

Pre-outage flow on the monitored line

$f_l^0 = 95.16MW$,

The power exchanged between the contingency bus and the reference bus: (5th column) of table 4

The corresponding sensitivity factors, (PTDF) of line 54 with respect to the contingency bus 1, bus 2, bus 20 and bus 25 which are 0.1619, 0.162, 0.0959 and 0.5726 respectively.

Bus 1: $\widehat{f_{54}} = PTDF_{1,27,54} * \Delta P_{1\ to\ 27} + f_{54}^0$

$$= 0.1619 * (150 - 10) + 95.16$$
$$= 117.826MW$$

Bus 2: $\widehat{f_{54}} = PTDF_{2,27,54} * \Delta P_{2\ to\ 27} + f_{54}^0$

$$= 0.162 * (300 - 600) + 95.16$$
$$= 46.56MW$$

Bus 20: $\widehat{f_{54}} = PTDF_{20,27,54} * \Delta P_{20\ to\ 27} + f_{54}^{0}$

$$= 0.0959 * (1000 - 900) + 95.16$$
$$= 104.75MW$$

Bus 25: $\widehat{f_{54}} = PTDF_{25,27,54} * \Delta P_{25\ to\ 27} + f_{54}^{0}$

$$= 0.5726 * (204 - 304) + 95.16$$
$$= 37.90MW$$

Notice that the values of flow estimated from PTDF match the DC load flow output reported in table 6.

Table 5: Predicted MW Flow at variable Generator Output

Line	BC	Predicted MW Flow				Line	BC	Predicted MW Flow			
Code	MW flow	140MW load Red at bus 1	50%Gen Red at bus 2	100mw Inc at bus 20	100mw Red at bus 25	Code	MW flow	140MW load Red at bus 1	50%Gen Red at bus 2	100mw Inc at bus 20	100mw Red at bus 25
L1	-150.00	-10.00	150.00	150.00	150.00	L40	147.00	147.00	-147.00	-147.00	-147.00
L2	225.00	295.00	-75.00	-225.00	-225.00	L41	197.00	197.00	-197.00	-197.00	-197.00
L3	225.00	295.00	-75.00	-225.00	-225.00	L42	197.00	197.00	-197.00	-197.00	-197.00
L4	437.90	446.67	-419.13	-435.87	-437.20	L43	57.20	52.34	-67.59	-58.31	-57.57
L5	437.90	446.67	-419.13	-435.87	-437.20	L44	-320.00	-320.00	320.00	320.00	320.00
L6	-91.90	-51.12	179.42	90.58	91.47	L45	504.10	491.42	-531.29	-507.06	-505.13
L7	-91.90	-51.12	179.42	90.58	91.47	L46	371.60	371.60	-371.62	-363.59	-371.62
L8	-91.90	-51.12	179.42	90.58	91.47	L47	300.00	300.00	-300.00	-300.00	-300.00
L9	250.00	250.00	-250.00	-250.00	-250.00	L48	-282.00	-311.53	218.71	314.86	276.03
L10	250.00	250.00	-250.00	-250.00	-250.00	L49	-282.00	-311.53	218.71	314.86	276.03
L11	175.00	175.00	-175.00	-175.00	-175.00	L50	-176.10	-106.10	326.06	126.06	226.06
L12	175.00	175.00	-175.00	-175.00	-175.00	L51	-176.10	-106.10	326.06	126.06	226.06
L13	275.40	284.17	-256.63	-273.37	-274.70	L52	-235.00	-235.00	235.00	235.00	235.00

L14	275.40	284.17	-256.63	-273.37	-274.70	L53	-235.00	-235.00	235.00	235.00	235.00
L15	-174.90	-161.06	204.58	184.97	178.40	L54	95.20	117.87	-46.59	-104.75	-37.90
L16	-174.90	-161.06	204.58	184.97	178.40	L55	227.50	227.50	-227.50	-227.50	-227.50
L17	-174.90	-161.06	204.58	184.97	178.40	L56	227.50	227.50	-227.50	-227.50	-227.50
L18	45.10	81.81	33.69	-60.61	-36.96	L57	69.60	69.60	-69.62	-61.59	-69.62
L19	2.90	47.06	91.85	-21.56	-22.85	L58	201.70	199.66	-206.12	-202.22	-201.90
L20	350.00	350.00	-350.00	-350.00	-350.00	L59	123.70	122.30	-126.72	-124.05	-123.83
L21	66.90	72.79	-54.40	-65.58	-66.47	L60	123.70	122.30	-126.72	-124.05	-123.83
L22	66.90	72.79	-54.40	-65.58	-66.47	L61	-0.40	-2.82	-4.78	-0.15	0.21
L23	66.90	72.79	-54.40	-65.58	-66.47	L62	-0.40	-2.82	-4.78	-0.15	0.21
L24	269.40	272.50	-262.69	-268.66	-269.13	L63	49.00	49.00	-49.00	-49.00	-49.00
L25	-159.30	-152.07	174.73	160.96	159.86	L64	49.00	49.00	-49.00	-49.00	-49.00
L26	-159.30	-152.07	174.73	160.96	159.86	L65	-282.10	-279.68	287.28	282.65	282.29
L27	-160.00	-160.00	160.00	160.00	160.00	L66	-282.10	-279.68	287.28	282.65	282.29
L28	142.70	164.22	-96.59	-151.81	-119.96	L67	-127.30	-105.78	173.41	118.19	150.04
L29	50.60	47.50	-57.31	-51.34	-50.87	L68	-8.80	13.87	57.41	-0.75	-33.90
L30	200.00	200.00	-200.00	-200.00	-200.00	L69	200.00	200.00	-200.00	-200.00	-200.00
L31	-380.60	-377.50	387.31	381.34	380.87	L70	-439.20	-430.44	457.93	441.19	439.86
L32	-147.00	-147.00	147.00	147.00	147.00	L71	-439.20	-430.44	457.93	441.19	439.86

L33	-323.20	-323.21	323.21	353.87	323.21	L72	189.90	188.35	-193.20	-190.23	-190.00
L34	-323.20	-323.21	323.21	353.87	323.21	L73	189.90	188.35	-193.20	-190.23	-190.00
L35	-323.20	-323.21	323.21	353.87	323.21	L74	146.70	144.66	-151.12	-147.22	-146.90
L36	118.80	112.92	-131.31	-120.13	-119.24	L75	-155.00	-155.00	155.00	155.00	155.00
L37	118.80	112.92	-131.31	-120.13	-119.24	L76	-155.00	-155.00	155.00	155.00	155.00
L38	118.80	112.92	-131.31	-120.13	-119.24	L77	-82.00	-82.00	82.00	82.00	82.00
L39	-338.40	-338.38	338.38	346.41	338.38						

Note: The negative sign on the flows simply mean that power flows in the opposite direction.

Table 6: Post Contingency Transmission Line Flow from DC load Flow Analysis

LC	BC	Bus 2	Bus 20	Bus25	LC	Bus 2	Bus 20	Bus25	Bus 2
L1	-150	-150.00	-150.00	-150.00	**L40**	147	147.00	147.00	147.00
L2	225	75.00	225.00	225.00	**L41**	197	197.00	197.00	197.00
L3	225	75.00	225.00	225.00	**L42**	197	197.00	197.00	197.00
L4	437.9	419.12	435.87	437.20	**L43**	57.2	67.59	58.31	57.58
L5	437.9	419.12	435.87	437.20	**L44**	-320	-320.00	-320.00	-320.00
L6	-91.9	-179.42	-90.58	-91.47	**L45**	504.1	531.28	507.06	505.14
L7	-91.9	-179.42	-90.58	-91.47	**L46**	371.6	371.62	363.59	371.62
L8	-91.9	-179.42	-90.58	-91.47	**L47**	300	300.00	300.00	300.00
L9	250	250.00	250.00	250.00	**L48**	-282	-218.70	-314.86	-276.03
L10	250	250.00	250.00	250.00	**L49**	-282	-218.70	-314.86	-276.03
L11	175	175.00	175.00	175.00	**L50**	-176	-326.06	-126.06	-226.06
L12	175	175.00	175.00	175.00	**L51**	-176	-326.06	-126.06	-226.06
L13	275.4	256.62	273.37	274.70	**L52**	-235	-235.00	-235.00	-235.00
L14	275.4	256.62	273.37	274.70	**L53**	-235	-235.00	-235.00	-235.00
L15	-175	-204.57	-184.97	-178.41	**L54**	**95.2**	**46.59**	**104.75**	**37.90**
L16	-175	-204.57	-184.97	-178.41	**L55**	227.5	227.50	227.50	227.50
L17	-175	-204.57	-184.97	-178.41	**L56**	227.5	227.50	227.50	227.50

L18	45.1	-33.69	60.61	36.96		**L57**	69.6	69.62	61.58	69.62
L19	2.9	-91.84	21.56	22.85		**L58**	201.7	206.12	202.22	201.91
L20	350	350.00	350.00	350.00		**L59**	123.7	126.74	124.05	123.83
L21	66.9	54.42	65.58	66.47		**L60**	123.7	126.74	124.05	123.83
L22	66.9	54.42	65.58	66.47		**L61**	-0.4	4.80	0.16	-0.21
L23	66.9	54.42	65.58	66.47		**L62**	-0.4	4.80	0.16	-0.21
L24	269.4	262.70	268.66	269.13		**L63**	49	49.00	49.00	49.00
L25	-159	-174.73	-160.96	-159.86		**L64**	49	49.00	49.00	49.00
L26	-159	-174.73	-160.96	-159.86		**L65**	-282	-287.30	-282.66	-282.29
L27	-160	-160.00	-160.96	-160.00		**L66**	-282	-287.30	-282.66	-282.29
L28	142.7	96.57	151.81	119.96		**L67**	-127	-173.43	-118.19	-150.04
L29	50.6	75.30	51.34	50.87		**L68**	-8.8	-57.41	0.75	33.90
L30	200	200.00	200.00	200.00		**L69**	200	200.00	200.00	200.00
L31	-381	-387.30	-381.34	-380.87		**L70**	-439	-457.94	-441.19	-439.86
L32	-147	-147.00	-147.00	-147.00		**L71**	-439	-457.94	-441.19	-439.86
L33	-323	-323.21	-353.86	-323.21		**L72**	189.9	193.21	190.23	189.99
L34	-323	-323.21	-353.86	-323.21		**L73**	189.9	193.21	190.23	189.99
L35	-323	-323.21	-353.86	-323.21		**L74**	146.7	151.12	147.22	146.91
L36	118.8	131.29	120.13	119.24		**L75**	-155	-155.00	-155.00	-155.00
L37	118.8	131.29	120.13	119.24		**L76**	-155	-155.00	-155.00	-155.00
L38	118.8	131.29	120.13	119.24		**L77**	-82	-82.00	-82.00	-82.00
L39	-338	-338.38	-346.41	-338.38						

V. CONCLUSION

The evolution of load flow analysis methods has made other power system related studies possible but has also resulted in increased complexity of analysis either at planning, operation or expansion stages. Despite the added complexity on account of increasing network size, this complexity inherently due to the nonlinear nature of the mathematical models of network parameters and their equations. State estimation technique is a viable alternative to AC load flow techniques in estimating network bus parameters from a known state necessary to estimate the line flow of any operating point. Transmission line flow estimates are also possible using DC load flow technique but certain enabling assumptions are the bases of the incompleteness and inexactness of its result when compared with the AC techniques. The justification to the use of DC load flow for quick estimation of transmission line flows is that its estimates compare proportionally to those from AC load flow so that they are effective when applied for contingency and security analyses. Now, the use of linear distribution factors in estimating transmission line flows from a known operation point yields faster results that match the estimations from DC load flow analysis. These sensitivity factors in the form of PTDF and LODF are calculated and stored for a network and remains valid for use as long as the network is unmodified with the addition of a bus, loads, generators or transmission lines. From any known operation point, the transmission line flow or loading/overload of any other operation point following the outage or variation of generator power output or the contingency of a transmission line may be estimated using the stored network values of Power Transfer Distribution Factors (PTDF) and Line Outage Distribution Factors (LODF). Unlike transmission flow results derived from AC techniques, PTDF and LODF flow estimates are not only non iterative but linear and has the exact value with flows from DC load flow analysis. This work using the Nigerian 330kV network of 41 bus demonstrates that

1. it is possible to predict transmission line flows besides using load flow analysis or state estimation which are dependent on convergence and telemetry accuracy respectively.
2. it is possible to evaluate the presence and extent of Transmission line overload after the contingency of a single critical network component be it a generator or transmission line.
3. this is a suitable alternate method for quick post contingency analysis in order to screen and rank N-1 (single component) contingencies as against using load flow or continuous load flow methods.

Two recommendations finally are offered for further work. Firstly, it may be observed that the values of PTDF and LODF reported in this work are Slack bus dependent. In other words, the procedure used for PTDF restricts the power transaction from any generator bus to the slack bus while other online generator buses are non participatory. The limitation of this restriction is that at a particular load demand the slack bus or the transmission lines attached to it may be operating at or near its limits and threaten the operation of the system. Using PTDF and LODF base on the participation of all online generators where power variation is distributed to generators based on a defined participation criterion. Secondly, the sensitivity factors of PTDF and LODF used are DC related has evidently has the comparative limitation of the DC load flow analysis technique. A new form of sensitivity factor base on the AC technique may be defined to estimate quicker results that are more exact to AC load flow result in other to provide alternatives estimate for expanded application like fault analysis. This Thesis focused on sensitivity factors for active power distribution, further studies can redirect focus on reactive power distribution in order to predict voltage stability.

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APPENDIX

Table I: Nigerian Network Generator Data showing output schedules and limits

Generation Station	Bus No	Pg (MW)	Q g	Q max	Q min	Voltage magnitude	MVA	Status	Pmax
Kainji	2	600.00	0	450	-300	1.01	100	1	760
Shiroro	4	275.00	0	400	-300	1.03	100	1	600
Jebba	6	500.00	0	400	-200	1.045	100	1	578.4
Olorunsogo	13	400.00	0	250	-190	1.02	100	1	760
Geregu	19	394.00	0	300	-300	1.00	100	1	414
Sapele	20	900.00	0	500	-500	1.00	100	1	1020
Delta	22	710.00	0	400	-100	1.00	100	1	840
Papalanto	25	304.00	0	350	-300	1.00	100	1	304
Egbin(slack)	27	900.97	0	1000	-1000	1.00	100	1	1320
Afam	29	450.00	0	560	-400	1.00	100	1	702
Alaoji	30	400.00	0	300	-100	1.00	100	1	1000
Okpai	31	450.00	0	400	-100	1.045	100	1	480
Mambila	34	130.88	0	1000	-1000	1.03	100	1	2600
Gurara	35	300.00	0	260	-200	1.00	100	1	300
Omoku	37	130.00	0	100	-100	1.02	100	1	150
Calabar	39	490.00	0	400	-400	1.00	100	1	561
Egbema	41	250.00	0	320	-200	1.03	100	1	338

Table II: Nigerian Network Bus data showing initial bus voltage magnitude and load schedules

Bus Name	Bus No	Bus Type	Pd (MW)	Q d (MVar)	Bs MVar	V m	Base Volt (KV)	V max	V min
Kebbi	1	1	150	60	0	0.998	330	1.05	0.95
Kainji	2	2	0	0	0	1.01	330	1.05	0.95
Jebba	3	1	350	195	0	1	330	1.05	0.95
Shiroro	4	2	250	160	0	1.03	330	1.05	0.95
Oshogbo	5	1	201	137	480	1	330	1.05	0.95
Jebba Gs	6	2	0	0	0	1.045	330	1.05	0.95
Katampe	7	1	350	220	0	1	330	1.05	0.95
Mando	8	1	200	125	77.83	1	330	1.05	0.95
Kumbotso	9	1	350	220	245.40	1	330	1.05	0.95
Jos	10	1	250	125	131.79	0.979	330	1.05	0.95
Gombe	11	1	160	95	144.38	1	330	1.05	0.95
Yola	12	1	160	90	0	1	330	1.05	0.95
Olunrunsogo	13	2	130	70	0	1.02	330	1.05	0.95
Damaturu	14	1	130	70	0	1	330	1.05	0.95
Maiduguri	15	1	200	150	188.59	1	330	1.05	0.95
Omotosho	16	1	300	188	254.8	1	330	1.05	0.95
Benin	17	1	157	80	77.14	1.01	330	1.05	0.95
Ajaokuta	18	1	100	55	0	1	330	1.05	0.95
Geregu	19	2	0	0	0	1	330	1.05	0.95
Sapele	20	2	0	0	0	1	330	1.05	0.95
Onitsha	21	1	115	42	0	1	330	1.05	0.95
Delta	22	2	0	0	0	1	330	1.05	0.95
Ikeja.west	23	1	429	248	50.16 1		330	1.05	0.95
Akangba	24	1	470	306	50.92	1.04	330	1.05	0.95
Papalanto	25	2	200	129	0	1	330	1.05	0.95
Aja	26	1	455	286	0	1	330	1.05	0.95

Egbim	27	3	0	0	0	1	330	1.05	0.95
Aladja	28	1	302	45	0	1	330	1.05	0.95
Afam	29	2	0	0	0	1	330	1.05	0.95
Alaoji	30	2	360	218	0	1	330	1.05	0.95
Okpai	31	2	130	80	0	1.045	330	1.05	0.95
New.Heaven	32	1	190	56	0	1	330	1.05	0.95
Ayede	33	1	139	61	0	1	330	1.05	0.95
Mambilla	34	2	130	60	0	1.03	330	1.05	0.95
Guarara	35	2	100	40	0	1	330	1.05	0.95
Markurdi	36	1	180	65	0	1	330	1.05	0.95
Omoku	37	2	185	79	0	1.02	330	1.05	0.95
Ikot Ekpene	38	1	140	70	0	1	330	1.05	0.95
Calabar	39	2	180	56	0	1	330	1.05	0.95
Owerri	40	1	180	75	0	1.03	330	1.05	0.95
Egbema	41	2	168	86	0	1	330	1.05	0.95

Table III: Nigerian Network Line Data showing Transmsission Line Parameters

Line-Index	From	To	R	X	B
1	1	2	0.01068	0.09246	1.2273
2	2	3	0.00289	0.02459	0.3178
3	2	3	0.00289	0.02459	0.3178
4	3	4	0.00853	0.07330	0.9625
5	3	4	0.00853	0.07330	0.9625
6	3	5	0.00557	0.04749	0.6172
7	3	5	0.00557	0.04749	0.6172
8	3	5	0.00557	0.04749	0.6172
9	6	3	0.00029	0.00243	0.0314
10	6	3	0.00029	0.00243	0.0314
11	4	7	0.00525	0.04479	0.5816
12	4	7	0.00525	0.04479	0.5816
13	4	8	0.00343	0.02913	0.3768
14	4	8	0.00343	0.02913	0.3768
15	5	17	0.00877	0.07535	0.9905
16	5	17	0.00877	0.07535	0.9905
17	5	17	0.00877	0.07535	0.9905
18	5	23	0.00880	0.07565	0.9945
19	5	33	0.00410	0.03486	0.4515
20	8	9	0.00671	0.05734	0.7477
21	8	10	0.00695	0.05942	0.7755
22	8	10	0.00695	0.05942	0.7755
23	8	10	0.00695	0.05942	0.7755
24	10	11	0.00923	0.07944	1.0465
25	10	36	0.00860	0.07389	0.9705
26	10	36	0.00860	0.07389	0.9705
27	12	11	0.00923	0.07944	1.0465
28	13	23	0.00463	0.03941	0.5104
29	14	11	0.00058	0.00489	0.0631
30	14	15	0.00431	0.03667	0.4752
31	14	34	0.00431	0.03667	0.4752
32	17	18	0.00688	0.05883	0.7676

33	17	20	0.00179	0.01519	0.1961
34	17	20	0.00179	0.01519	0.1961
35	17	20	0.00179	0.01519	0.1961
36	17	21	0.00487	0.04149	0.5382
37	17	21	0.00487	0.04149	0.5382
38	17	21	0.00487	0.04149	0.5382
39	17	22	0.00343	0.02913	0.3768
40	18	17	0.00688	0.05883	0.7676
41	19	18	0.00018	0.00152	0.0196
42	19	18	0.00018	0.00152	0.0196
43	21	30	0.00490	0.04179	0.5422
44	21	31	0.00487	0.04149	0.5382
45	21	32	0.00286	0.02429	0.3139
46	22	28	0.00115	0.00973	0.0000
47	23	16	0.00573	0.04863	0.0000
48	23	17	0.00688	0.05883	0.7676
49	23	17	0.00688	0.05883	0.7676
50	23	27	0.00222	0.01883	0.2432
51	23	27	0.00222	0.01883	0.2432
52	24	23	0.00061	0.00517	0.0667
53	24	23	0.00061	0.00517	0.0667
54	25	23	0.00430	0.03647	0.0000
55	27	26	0.00050	0.00426	0.0549
56	27	26	0.00050	0.00426	0.0549
57	28	20	0.00225	0.01913	0.2471
58	29	37	0.00118	0.01003	0.1294
59	29	38	0.00286	0.02429	0.3139
60	29	38	0.00286	0.02429	0.3139
61	30	29	0.00058	0.00489	0.0631
62	30	29	0.00058	0.00489	0.0631
63	30	40	0.00321	0.02731	0.3532
64	30	40	0.00321	0.02731	0.3532
65	32	38	0.00286	0.02429	0.3139
66	32	38	0.00286	0.02429	0.3139
67	33	13	0.00214	0.01818	0.2356
68	33	25	0.00215	0.01822	0.2354
69	35	8	0.00304	0.02580	0.3336
70	36	32	0.00867	0.07447	0.9785
71	36	32	0.00867	0.07447	0.9785
72	36	34	0.01150	0.09988	1.3325
73	36	34	0.01150	0.09988	1.3325
74	37	38	0.00079	0.00669	0.0863
75	38	39	0.00257	0.02186	0.2825
76	38	39	0.00257	0.02186	0.2825
77	40	41	0.00318	0.02701	0.3493