On The Cost Implications of Technical Energy Losses on Nigerian 330-kV Transmission Grid System

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Abstract: Base on the author's result of power line losses obtained for low, medium and high current levels as 146.73MW, 322.24MW and 738.28MW respectively, in his bid to evaluate the power line losses using symmetrical component theory of unbalanced fault, the annual energy (MWH) losses for year 2013 was calculated and validated in this study. The annual technical energy losses due to the low, medium and high power losses were respectively found to be 443.45GWH, 976.895GWH and 2231.230GWHbased on Load Factor and Load Loss Factor amounting to N8.4 billion, N18.6 billion and N42.4 billion respectively. The low power loss (steady-state) result of this work was validated by the result of load-flow obtained using the MATLAB and Power Word Simulator (PWS) while the annual MWH for the high power loss level compares favourably well with the normal practice of utility operator's monthly energy balance thereby closing the gap between the practical information and the theoretical one.

Keywords: Power line losses, Current levels, Load Factor, Load Loss Factor, Load-Flow

1. Introduction

Power quality has become an important issue for maximum efficiency operation of energy that is delivered to transmission and distribution line. The more the power that flows through the network, the more the current and hence the voltage drop becomes more excessive and power quality declines. The global problem of the lower power availability to consumers is a consequence of power loss and no matter how carefully the power system network is designed, losses are inevitable. Loss of power on transmission lines is a global problem and it is necessary to state here that the losses on transmission lines can result into line outages in the electric power system. The existing transmission system in Nigeria is characterized by high line losses and several outages leading to interruption of systems and equipment. Nigerian electricity grid has a large proportion of transmission and distribution losses, and these amounts to a whopping 44.5% of generation [1]. Based on the Power Holding Company of Nigeria (PHCN) annual reports for the 2004 and 2005, the transmission line losses alone were estimated to be 9.2% [2]. Countries such as China that have attached importance to loss minimization to enhance efficiency have about 13% transmission and distribution losses with India having about 23% [3]. The losses in some other countries like Iraq, Moldova, Sudan, Venezuelan RB, Syria, Korea Republic, Yemen Republic, Pakistan, Tanzania, México, Taiwan, U.S.A, and Japan are 42, 40, 28, 27, 26, 25, 22, 20, 16, 9, 6 and 5% respectively [4].

However, going by the available data and tools needed for calculating technical losses in power system, current techniques have certain drawbacks regarding such calculations.Moreover, literature reveals different methods of loss estimation but the existing approaches focus mainly on theoretical calculation and probabilistic data that are based on simple model data, insufficient to give a correct evaluation assessment of losses [5]. Hence, there is still a clear gap between practical information and the theoretical one which tends to be poor and not precise [6] and the reduction of system losses is analyzed on the accuracy of the technical losses. To solve the challenging problems inherent in designing future power systems to deliver increasing amounts of electrical energy in a safe, clean and economical manner [7], a regular and fairly accurate description of power losses as a function of time to make a reliable prediction of energy losses is required. The objective of this study, therefore, is to evaluate the technical losses in and its cost implication on Nigeria 330kV power transmission system.

2. Methodology

The methodology adopted for this study is the analysis of the disturbances brought about by the faults followed by the procedure for maximum line currents determination that is used to calculate the power losses and the values are used thereafter to evaluate the annual energy losses and its cost implications in the Nigeria 330-kV power transmission system. Results analysis of load-flows using the code-based MATLAB and Power World Simulation model-based software are presented and discussed.

2.1 Disturbances in Nigeria 330-kV Transmission System

Table 2.1 gives the summary of the yearly energy balance that reflects a total loss of 14204.74GWH from 2005 to 2011 as reported in the PHCN monthly energy balance summary.. These transmission losses - calculated to be approximately 10.05% of the energy fed into the grid [8], clearly show that majority of the outages in NESI are responsible for the problem in the transmission network.

| Year | Energy Delivered to Transmission Line (GWH) | Energy Available for Sale (GWH) | Transmission Line energy Losses (GWH) | Line Losses Percentage of Energy Delivered (%) |
|------|--|------------------------------------|--|---|
| 2005 | 23,403.26 | 21,401.87 | 2,001.39 | 8.55 |
| 2006 | 22,576.02 | 21,024.39 | 1,551.63 | 6.87 |
| 2007 | 22,255.76 | 20,419.07 | 1,836.69 | 8.25 |
| 2008 | 20,765.71 | 18,885.51 | 1,880.19 | 9.05 |
| 2009 | 20,329.45 | 18,620.10 | 1,709.35 | 8.41 |
| 2010 | 24,362.42 | 2,1931.67 | 2,430.75 | 9.98 |
| 2011 | 26,999.35 | 24,,204.62 | 2,794.73 | 10.35 |
| | Total: 160,691.9 | 7 | 14,204.74 | 8.84 |

 Table, 2.1: (Yearly energy balance summary 2005-2011)

2.2. Overview of the Nigerian 330-kV Transmission Network

The Nigerian Transmission system is made up of interconnected network of 5,650km of 330kV that spans the country nationwide. The single-line diagram of the Nigerian 330-kV network currently consists of sixty 330-kV transmission line circuits, eight effective generating stations, twenty load stations, twenty-eight buses (substations), and thirty-three transmission lines as shown in figure 2.1

The system may be divided into three geographical zones-North, South-East, and the South-West. The North is connected to the South through the one-triple circuit lines between Jebba and Oshogbo while the West is linked to the East through one transmission line from Oshogbo to Benin and one double line from Ikeja to Benin. The transmission grid is centrally controlled from the National Control centre (NCC) located at Oshogbo in Osun State, while there is a back-up or Supplementary National Control Centre (SNCC) at Shiroro in Niger State. In addition to these two centres are three Regional Control Centres (RCCs) located at Ikeja West (RCC1), Benin (RCC2) and Shiroro (RCC3) substations [9].



Figure 2.1: The Nigerian 330-kV Transmission System

3. Results and Discussion

3.1. Load-Flow Analysis of the Existing Nigerian 330kV Transmission Network

In order to perform a power flow analysis using the Newton-Raphson (N-R) method program in the MATLAB environment, the one-line diagram of the existing Nigerian 330.kV network is redrawn using E-draw max as shown in figure 2.1 for clear identification of buses and branches in the network. This study is carried out majorly using statistical measures of central tendency to analyse data gotten from the nation's National Control Centre (NCC),

Oshogbo and some of the generating stations in the country [10].

However, from the convergence of N.R load-flow results of table 3.1, a summarized result of active power, reactive power and complex power flow at each bus and the line flow is as presented in table 3.1.The total active power loss from the power flow program solutions by Newton-Raphson method is 203.620 MW and that of the reactive power loss is -1556.448 Mvar.

Table 3.1: Summary of load-flow results of N-R

| Image (AW) (AWa) (AWa) (AWa) (AWa) 1 2 115879 50.724 119.9885 [4.879] 11.602 2 1 1143.9 -85.9 143.14 [4.879] -11.602 3 1 -490.99 4.326 490.049 6.63.3 -11.502 3 5 23.1866 13.46 490.049 6.63.3 -11.502 3 5 23.1866 13.46 52.119 5.6016 -77.1002 3 3 3 1.62.35 495.062 32.92.211 5.6016 -77.1002 5 6 177.026 42.856 182.029 1.0055 -93.4136 6 7 -80.773 -56.0753 56.0753 -77.7844 -16.77.77.7844 6 7 -17.54496 -11.1164 20.02.965 1.5765 -77.77.7844 6 7 -17.54496 -11.81042 1.65.172.3 10.0055 -93.4136 6 <t< th=""><th>From Bus</th><th>To Bus</th><th>Active Power flow</th><th>Reactive Power flow</th><th>Complex Power flow</th><th>Active Power loss</th><th>Reactive Power loss</th></t<> | From Bus | To Bus | Active Power flow | Reactive Power flow | Complex Power flow | Active Power loss | Reactive Power loss |
|--|-----------|----------------------|----------------------|---------------------|----------------------|-------------------|---------------------|
| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 1 Tom Dus | 10 Bus | (<i>MW</i>) | (Mvar) | (MVA) | (MW) | (Mvar) |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 1 | 2 | 115.9879 | -30.7254 | 119.9885 | 1.4879 | -116.625 |
| 2 1 -114.5 -85.9 145.14 14879 -116.625 3 4 -494.329 -38.5246 495.8279 0.671 -2.3843 3 5 21.3486 13.46 222.117 5.0016 -78.1002 3 23 65.63715 -2.64843 652.1197 2.6616 -77.1002 5 6 177.026 42.3566 182.0291 1.5765 -71.7594 5 8 128.921 11.3987 129.9265 1.5765 -71.7594 6 7 -80.9763 -36.6775 88.894 0.1617 -34.9999 7 6 81.138 1.6816 73.138 0.6817 -17.1784 7 6 81.338 1.6816 73.138 0.6617 -34.9999 7 8 73.662 -1.6816 73.6182 0.6777 -17.1784 8 5 -12.9155 -1.04.8124 1.65.723 1.0055 -39.4136 8 9 </td <td>1</td> <td>3</td> <td>501.7121</td> <td>-55.2062</td> <td>504.7403</td> <td>6.633</td> <td>-11.5062</td> | 1 | 3 | 501.7121 | -55.2062 | 504.7403 | 6.633 | -11.5062 |
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| 3 5 324.8566 13.46 322.1179 5.6016 -78.1002 4 3 495 36.1403 496.3176 0.671 -2.3843 5 3 -136.235 -91.5602 229.221 5.6016 -78.1002 5 6 177.026 42.3656 182.0249 1.5765 -71.7594 5 6 177.026 42.3656 182.0249 1.5765 -71.7594 6 7 -89.9763 -36.0775 98.8954 0.1617 -34.9959 6 8 -193.741 -56.0066 59.2639 0.0222 -98.1078 7 6 81.138 1.6816 81.1554 0.1617 -34.9959 7 7.8 73.6062 -1.0816 73.8122 0.06577 -17.1578 8 5 -127.9155 104.8174 165.3732 1.0055 -93.4136 8 10 -40.38922 -362.0502 542.4106 6.43733 2.3104 8 | 3 | 4 | -494.329 | -38.5246 | 495.8279 | 0.671 | -2.3843 |
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| 8 7 -73.6044 -15.4763 75.2138 0.0677 -17.1578 8 10 -403.8922 -362.0502 542.4106 -4373 2.3304 8 12 -44.8346 -59.1121 74.1915 1.2761 -96.9254 8 13 -250.0452 -126.1513 280.0556 6.7175 -147.3841 9 8 -244.7 -258.5 355.9499 2.9955 -22.7065 10 11 276.706 169.1378 324.3051 2.306 -36.6622 10 13 -196.7158 18.1493 197.5513 2.8778 -27.954 11 10 -274.4 -205.8 343 2.306 -36.6622 12 13 54.4993 37.8133 66.3244 0.3626 -83.348 13 10 199.5937 -46.1033 204.8491 2.8778 -27.954 13 12 -54.1266 -121.1613 132.7018 0.3626 -83.348 | 8 | 6 | 19.3963 | -42.1012 | 46.3544 | 0.0222 | -98.1078 |
| 8 9 247,6955 235,7035 341,9199 2.9955 -22,7965 8 12 -44,8346 -50,1121 74,1915 1.2761 -96,9254 8 13 -50,0452 -126,1513 280,0656 6,7175 -147,73841 9 8 -244,7 -258,5 355,9499 2.9955 -22,7965 10 11 276,766 169,1578 324,4051 2.306 -36,6622 10 13 -196,7158 18,1493 197,5513 2.8778 -27,954 11 10 -274,4 -205,8 343 2.306 -36,6622 12 8 46,1107 -37,8133 56,6326 1.2761 -96,9254 13 5 194,15 -59,4926 203,0606 3.238 -172,5968 13 10 199,5937 -46,1033 204,48491 2.8778 -27,954 13 14 14,1081 -155,6499 156,2934 0.3681 -165,9499 | 8 | 7 | -73.6044 | -15.4763 | 75.2138 | 0.0577 | -17.1578 |
| 8 10 -403.8922 -362.0502 542.4106 6.4373 2.3304 8 13 -250.0452 -126.1513 280.0656 6.7175 -147.3841 9 8 -244.7 -258.5 355.9499 2.9955 -22.7965 10 8 410.3295 364.3806 548.7654 6.4373 2.3304 10 11 276.706 169.1378 324.3051 2.3078 -27.954 11 10 -274.4 -20.5.8 343 2.306 -36.6622 12 8 46.1107 -37.8133 66.3224 0.3626 -83.348 13 5 194.15 -59.4926 203.0606 3.238 -172.5968 13 10 199.5937 -44.0103 204.8491 2.8778 -27.954 13 12 -54.1266 -121.1613 132.7018 0.3626 -83.348 13 14 14.1681 -155.6499 156.2934 0.3681 -165.49499 | 8 | 9 | 247.6955 | 235.7035 | 341.9199 | 2.9955 | -22.7965 |
| 8 12 -44.8346 -59.112 74.1915 1.2761 -96.0254 8 13 -250.0452 -126.1513 280.0656 6.7175 -147.3841 9 8 244.7 -258.5 355.9499 2.9955 -22.7965 10 8 410.3295 364.3806 548.7654 6.4373 2.304 10 13 -196.7158 18.1493 197.5513 2.8778 -27.954 11 10 -274.4 -205.8 343 2.306 -36.6622 12 8 461.107 -37.8133 59.6326 1.2761 -96.9254 13 5 194.15 -59.4926 203.0606 3.238 -172.5968 13 10 199.5937 -46.1033 204.8491 2.8778 -27.954 13 12 -54.1266 -121.1613 132.7018 0.3626 -83.348 13 14 14.1681 -155.6499 132.2018 0.3626 -83.348 < | 8 | 10 | -403.8922 | -362.0502 | 542.4106 | 6.4373 | 2.3304 |
| 8 13 -250,0452 -126,1513 280,0556 6,7175 -147,3841 9 8 -244,7 -258,5 355,9499 2.9955 -22,7965 10 11 276,706 169,1378 324,3051 2,306 -36,6622 10 13 -196,7158 18,1493 197,5513 2,8778 -27,954 11 10 -274,4 -205,8 343 2,306 -36,6622 12 13 54,4893 37,8133 66,3244 0,3626 -83,348 13 5 194,15 -59,4926 203,0606 3,238 -17,2568 13 8 256,7627 -21,2328 237,6391 6,7175 -147,3841 13 10 199,5937 -46,1033 204,8491 2,8778 -27,954 13 14 14,1681 -155,6499 156,2934 0,3681 -165,9499 13 14 -27,5321 123,0107 284,302 4,4327 -70,3566 | 8 | 12 | -44.8346 | -59.1121 | 74.1915 | 1.2761 | -96.9254 |
| 9 8 -244.7 -258.5 355.9499 2.9955 -22.7965 10 11 276.706 169.1378 324.3051 2.306 -36.6622 10 13 -196.7158 18.1493 197.5513 2.8778 -27.954 11 10 -274.4 -205.8 343 2.306 -36.6622 12 8 46.1107 -37.8133 59.6326 1.2761 -96.9524 13 5 194.15 -59.4926 203.0606 3.238 -172.5968 13 5 194.15 -59.4926 203.0606 3.238 -172.5968 13 10 199.5937 -46.1033 204.8491 2.8778 -27.954 13 12 -54.1266 -121.1613 132.7018 0.3681 -165.9499 13 15 -26.24.152 -26.578 263.7962 1.1368 -36.882 13 16 -473.9006 20.0871 474.3261 4.78111 -12.9197 | 8 | 13 | -250.0452 | -126.1513 | 280.0656 | 6.7175 | -147.3841 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 9 | 8 | -244.7 | -258.5 | 355.9499 | 2.9955 | -22.7965 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 10 | 8 | 410.3295 | 364.3806 | 548.7654 | 6.4373 | 2.3304 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 10 | 11 | 276.706 | 169.1378 | 324.3051 | 2.306 | -36.6622 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 10 | 13 | -196.7158 | 18.1493 | 197.5513 | 2.8778 | -27.954 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 11 | 10 | -274.4 | -205.8 | 343 | 2.306 | -36.6622 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 12 | 8 | 46.1107 | -37.8133 | 59.6326 | 1.2761 | -96.9254 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 12 | 13 | 54.4893 | 37.8133 | 66.3244 | 0.3626 | -83.348 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 5 | 194.15 | -59.4926 | 203.0606 | 3.238 | -172.5968 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 8 | 256.7627 | -21.2328 | 257.6391 | 6.7175 | -147.3841 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 10 | 199.5937 | -46.1033 | 204.8491 | 2.8778 | -27.954 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 12 | -54.1266 | -121.1613 | 132.7018 | 0.3626 | -83.348 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 14 | 14.1681 | -155.6499 | 156.2934 | 0.3681 | -165.9499 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 15 | -262.4152 | -26.9578 | 263.7962 | 1,1368 | -36.8382 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 16 | -473,9006 | 20.0871 | 474.3261 | 4.7811 | -12.9197 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 13 | 18 | -257,5321 | 123.0107 | 285.4022 | 4.4327 | -70.3566 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 14 | 13 | -13.8 | -10.3 | 17.22 | 0.3681 | -165,9499 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 15 | 13 | 263.552 | -9.8805 | 263.7372 | 1.1368 | -36.8382 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 15 | 17 | -93.852 | 3,7389 | 93.9265 | 0.2026 | -50.8631 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 16 | 13 | 478.6817 | -33,0068 | 479.8183 | 4.7811 | -12,9197 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 16 | 17 | 191 3183 | -28 4304 | 193 4192 | 0.7637 | -46 2284 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 17 | 15 | 94.0547 | -54.602 | 108.755 | 0.2026 | -50.8631 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 17 | 16 | -190,5547 | -17.798 | 191.384 | 0.7637 | -46.2284 |
| 10 10 100000 100000 100000 100000 18 19 -703.8188 82.449 708.6316 46.1812 14.2387 18 20 178.7979 112.9396 211.4806 1.7979 -20.4604 18 22 78.4561 -140.4214 160.8525 7.0193 -97.1128 19 18 750 -68.2103 753.0954 46.1812 14.2387 20 18 -177 -133.4 221.6406 1.7979 -20.4604 21 22 378.5 359.6307 522.1077 22.9367 -3.8779 22 18 -71.4367 43.3086 83.5394 7.0193 -97.1128 22 21 -355.5633 -363.5086 508.4916 22.9367 -3.8779 23 3 -629.9212 102.0904 638.1404 26.6503 75.2551 23 24 294.9635 64.7522 301.9873 4.8635 -80.2478 23 | 18 | 13 | 261,9648 | -193 3673 | 325,6017 | 4,4327 | -70.3566 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 18 | 19 | -703 8188 | 82 449 | 708 6316 | 46 1812 | 14 2387 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 18 | 20 | 178 7979 | 112 9396 | 211 4806 | 1 7979 | -20 4604 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 18 | 20 | 78 4561 | -140 4214 | 160 8525 | 7 0193 | _97 1128 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 10 | 18 | 750 | -68 2103 | 753 0954 | 46 1812 | 14 2387 |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$ | 20 | 18 | _177 | _133.4 | 221 6406 | 1 7070 | _20.4604 |
| 21 22 378.5 353.0307 322.1077 22.9307 -53.077 22 18 -71.4367 43.3086 83.5394 7.0193 -97.1128 22 21 -355.5633 -363.5086 508.4916 22.9367 -3.8779 23 3 -629.9212 102.0904 638.1404 26.6503 75.2551 23 24 294.9635 64.7522 301.9873 4.8635 -80.2478 23 25 653.5577 486.4913 814.7463 21.1085 145.1124 24 23 -290.1 -145 324.3193 4.8635 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 20 | 22 | -1// | 250 6207 | 522 1077 | 22 0267 | -20.4004 |
| 22 16 -71.4507 45.5060 65.5374 7.0195 -97.1128 22 21 -355.5633 -363.5086 508.4916 22.9367 -3.8779 23 3 -629.9212 102.0904 638.1404 26.6503 75.2551 23 24 294.9635 64.7522 301.9873 4.8635 -80.2478 23 25 653.5577 486.4913 814.7463 21.1085 145.1124 24 23 -290.1 -145 324.3193 4.8635 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 <td>21</td> <td>18</td> <td>_71 /267</td> <td>12 2086</td> <td>82 520/</td> <td>7 0102</td> <td>_07 1129</td> | 21 | 18 | _71 /267 | 12 2086 | 82 520/ | 7 0102 | _07 1129 |
| 22 21 -555.5055 -505.5060 506.4910 22.9507 -5.8779 23 3 -629.9212 102.0904 638.1404 26.6503 75.2551 23 24 294.9635 64.7522 301.9873 4.8635 -80.2478 23 25 653.5577 486.4913 814.7463 21.1085 145.1124 24 23 -290.1 -145 324.3193 4.8635 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 26 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 22 | 21 | -/1.430/ | -13.3000 | 508 A016 | 22 0267 | -77.1120 |
| 2.5 5 -027.7212 102.0904 058.1404 20.0505 75.251 23 24 294.9635 64.7522 301.9873 4.8635 -80.2478 23 25 653.5577 486.4913 814.7463 21.1085 145.1124 24 23 -290.1 -145 324.3193 4.8635 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 26 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 22 | 21 | -333.3033 | -303.3080 | 628 1404 | 22.7307 | -3.0/19 |
| 2.5 24 274.7053 04.7322 501.9675 4.8653 -80.2478 23 25 653.5577 486.4913 814.7463 21.1085 145.1124 24 23 -290.1 -145 324.3193 4.8635 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 23 | 21 21 | -029.9212 | 64 7500 | 201 0272 | <u> </u> | 20 2470 |
| 2.5 2.5 0.53.577 460.4915 814.7405 21.1065 145.1124 24 23 -290.1 -145 324.3193 4.8635 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 23 | 2 4 25 | 274.7033 652 5577 | 486 4012 | 301.70/3 814 7462 | 4.0033 | -00.2478 |
| 24 25 -290.1 -145 324.3195 4.8655 -80.2478 25 23 -632.4492 -341.3789 718.7013 21.1085 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 23 | 23 | 200.1 | 400.4913 | 014./403 | 4 9625 | 143.1124 |
| 2.5 2.5 -052.4472 -541.5769 /16.7015 21.1065 145.1124 25 26 230.5674 155.9158 278.3362 9.9674 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 26.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 24 | 23 | -290.1 | -143 | 324.3193 718 7012 | 4.0033 | -00.2478 |
| 2.5 2.6 2.50.3074 155.9158 278.3502 9.9074 13.0158 25 27 208.8818 40.7631 212.8221 4.8743 -25.2542 26 25 -220.6 -142.9 262.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 23 | 23 | -032.4492 | -341.3/89 | /10./015 | 21.1083 | 143.1124 |
| 23 27 208.8816 40.7051 212.8221 4.8743 -25.2342 26 25 -220.6 -142.9 262.8398 9.9674 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 23 | 20 | 230.30/4 | 133.9138 | 2/0.002 | 9.90/4 | 13.0138 |
| 20 23 -220.0 -142.9 202.8398 9.96/4 13.0158 27 25 -204.0075 -66.0173 214.4233 4.8743 -25.2542 | 23 | 21 | 208.8818 | 40./031 | 212.8221 | 4.8/45 | -23.2342 |
| 21 23 -204.0073 -00.0175 214.4233 4.8743 -25.2542 Total 203.62 1556.45 | 20 | 25 | -220.6 | -142.9 | 202.8398 | 9.90/4 | 13.0138 |
| | 21 | 23 | -204.00/3 | -00.01/3 | 214.4233 1556 45 | 4.8/43 | -23.2342 |

Another load-flow analysis was carried out on the same 330-kV transmission network (for the purpose of comparison) using the run mode of power world simulator [11]. The line flows and power losses are as presented in table 3.2. The load-flow is performed at a steady state and therefore these results are obtained under normal condition. The load-flow analysis was performed at a

steady state; the power-flow solution results obtained for PWS and MATLAB software are compared with the results of low power obtained from LC that is likened to the current that flows under a steady-state condition for validation.



Figure 3.1: The Simulation run Mode of Existing Nigerian 330-kV Transmission Network

| Table | 3.2: | Line- | -Flows | and | Power | losses | for | PWS | Model | -Based | Netwo | ork |
|--------|------|-------|--------|-----|--------|---------|-----|--------|---------|--------|---------|-----|
| I abic | ··-· | Line | 11000 | unu | 100001 | 1000000 | 101 | 1 11 0 | 1110401 | Dubeu | 1100000 | OIN |

| From Bus No | From Name | To Bus No | To Name | Circuit | MW From | Mvar From | MVA From | MW Loss | Mvar Loss |
|----------------|-----------|-----------------|--------------|---------|---------|--------------|-------------|---------|-----------|
| 1 | Kainji | 2 | Birnin-Kebbi | 1 | 116.7 | 48.5 | 126.4 | 2.2 | -37.42 |
| 1 | Kainji | 3 | Jebba TS | 1 | 250.5 | -36.7 | 253.2 | 1.83 | -15.25 |
| 1 | Kainji | 3 | Jebba TS | 2 | 250.5 | -36.7 | 253.2 | 1.83 | -15.25 |
| 3 | Jebba TS | 4 | Jebba GS | 1 | -247.3 | 31.8 | 249.4 | 0.19 | -2.07 |
| 3 | Jebba TS | 4 | Jebba GS | 2 | -247.3 | 31.8 | 249.4 | 0.19 | -2.07 |
| 3 | Jebba TS | 5 | Oshogbo | 1 | 116.7 | -10.7 | 117.2 | 0.78 | -52.18 |
| 3 | Jebba TS | 5 | Oshogbo | 2 | 116.7 | -10.7 | 117.2 | 0.78 | -52.18 |
| 3 | Jebba TS | 5 | Oshogbo | 3 | 116.7 | -10.7 | 117.2 | 0.78 | -52.18 |
| 3 | Jebba TS | 23 | Shiroro | 1 | 315.5 | -41.3 | 318.1 | 6.67 | -22.81 |
| 3 | Jebba TS | 23 | Shiroro | 2 | 315.5 | -41.3 | 318.1 | 6.67 | -22.81 |
| 5 | Oshogbo | 6 | Ayede | 1 | 192.3 | 3.5 | 192.3 | 1.59 | -28.35 |
| 5 | Oshogbo | 8 | Ikeja-West | 1 | 130 | -9.9 | 130.4 | 1 | -48.67 |
| 5 | Oshogbo | 13 | Benin | 1 | -175.8 | -20 | 176.9 | 2.89 | -68.38 |
| 6 | Avede | 7 | Papalanto | 1 | -70.7 | -153.2 | 168.7 | 0.6 | -13.71 |

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| 6 | Ayede | 8 | Ikeja-West | 1 | -14.4 | -21.8 | 26.1 | 0.01 | -49.07 |
|----|------------|----|------------|---|--------|--------|-------|--------|---------|
| 7 | Papalanto | 8 | Ikeja-West | 1 | 83.5 | 303.9 | 315.1 | 1.02 | 0.24 |
| 8 | Ikeja-West | 9 | Akangba | 1 | 123.1 | 111.1 | 165.8 | 0.71 | -18.1 |
| 8 | Ikeja-West | 9 | Akangba | 2 | 123.1 | 111.1 | 165.8 | 0.71 | -18.1 |
| 8 | Ikeja-West | 10 | Egbin | 1 | -195.9 | -144.2 | 243.3 | 1.3 | -14.55 |
| 8 | Ikeja-West | 10 | Egbin | 2 | -195.9 | -144.2 | 243.3 | 1.3 | -14.55 |
| 12 | Omotosho | 8 | Ikeja-West | 1 | 44.5 | -15.2 | 47 | 0.12 | -39.71 |
| 8 | Ikeja-West | 13 | Benin | 1 | -246 | -13.8 | 246.4 | 6.53 | -43.48 |
| 10 | Egbin | 11 | Aja | 1 | 137.6 | 82.5 | 160.5 | 0.62 | -20.39 |
| 10 | Egbin | 11 | Aja | 2 | 137.6 | 82.5 | 160.5 | 0.62 | -20.39 |
| 10 | Egbin | 13 | Benin | 1 | -247.3 | 52.6 | 252.8 | 5.1 | 19.63 |
| 10 | Egbin | 29 | AES | 1 | 0 | 0 | 0 | 0 | 0 |
| 12 | Omotosho | 13 | Benin | 1 | 56.1 | -0.6 | 56.1 | 0.15 | -36.88 |
| 13 | Benin | 14 | Ajaokuta | 1 | 7 | -68.7 | 69.1 | 0.08 | -73.86 |
| 13 | Benin | 14 | Ajaokuta | 2 | 7 | -68.7 | 69.1 | 0.08 | -73.86 |
| 13 | Benin | 15 | Sapele | 1 | -145.6 | -54.3 | 155.4 | 0.42 | -17.34 |
| 13 | Benin | 15 | Sapele | 2 | -145.6 | -54.3 | 155.4 | 0.42 | -17.34 |
| 13 | Benin | 16 | Delta | 1 | -445 | 14.4 | 445.3 | 4.65 | 14.76 |
| 13 | Benin | 18 | Onitsha | 1 | -288.7 | 91.3 | 302.8 | 4.84 | -8.72 |
| 15 | Sapele | 17 | Aladja | 1 | -122.3 | 38 | 128.1 | 0.4 | -20.43 |
| 16 | Delta | 17 | Aladja | 1 | 220.3 | -0.5 | 220.3 | 1.12 | -14.5 |
| 19 | Okpai | 18 | Onitsha | 1 | 375 | 23 | 375.7 | 12.73 | -0.14 |
| 19 | Okpai | 18 | Onitsha | 2 | 375 | 23 | 375.7 | 12.73 | -0.14 |
| 18 | Onitsha | 20 | New Haven | 1 | 178.6 | 116.6 | 213.3 | 1.6 | -16.81 |
| 18 | Onitsha | 22 | Alaoji | 1 | 67.8 | -108.8 | 128.2 | 6.17 | -43.72 |
| 22 | Alaoji | 21 | Afam | 1 | -182.7 | -192.6 | 265.5 | 6.57 | -4.98 |
| 22 | Alaoji | 21 | Afam | 2 | -182.7 | -192.6 | 265.5 | 6.57 | -4.98 |
| 23 | Shiroro | 24 | Katampe | 1 | 146.3 | 27.5 | 148.9 | 1.27 | -44.99 |
| 23 | Shiroro | 24 | Katampe | 2 | 146.3 | 27.5 | 148.9 | 1.27 | -44.99 |
| 23 | Shiroro | 25 | Kaduna | 1 | 321.8 | 220.8 | 390.2 | 5.46 | 13.19 |
| 23 | Shiroro | 25 | Kaduna | 2 | 321.8 | 220.8 | 390.2 | 5.46 | 13.19 |
| 25 | Kaduna | 26 | Kano | 1 | 229.1 | 151.6 | 274.7 | 8.48 | 8.72 |
| 25 | Kaduna | 27 | Jos | 1 | 210.5 | 118.8 | 241.7 | 5.5 | -9.88 |
| 27 | Jos | 28 | Gombe | 1 | 134.7 | 76 | 154.7 | 4.12 | -21.87 |
| | | | | | | | | 136.13 | -1057.4 |

3.2. Procedure for Maximum Line Currents

Determination on the Test System

The results of all the line current magnitudes obtained in the simulation of various aspects of faults on the threephase power line of the test system are analysed or streamlined in order to rigorously establish a categorical data of maximum line current magnitudes. The results of this analysis are generated for two scenarios: case 1 is when the fault impedance is 0.1 and case 2 when the fault impedance is set to zero.

The case 2 (i.e. $Z_f = 0$) is one extreme considered in the determination of maximum current on the test system and it forms the category that creates tremendous amount of current comparable to the maximum current of the fault impedance, $Z_f = 0.1$. A tabular summary and graphical representation of the results obtained for the two configurations are presented in tables3.3 and 3.4 for $Z_f =$ j0.1 and for $Z_f = j0$ respectively for the line current magnitude to determine the available maximum current on each line for all the various types of asymmetrical fault considered. The faulted bus locations that cause the maximum current are also presented. Tables 3.3 and 3.4 presentlocation and the corresponding maximum line current that is available on the three-phase line of the test system when SLG, LL and DLG faults are simulated with fault impedances of j0.1 and j0 respectively.

Table 3.3: Maximum line current caused by SLG, LL, DLG and Location when $Z_f = j0.1$

| From - To bus | SLG (pu) | Location | L - L (pu) | Location | DLG (pu) | Location |
|------------------|----------------------|-------------|----------------------|-------------|----------------------|-------------|
| 1-2 | 4.7596 | BirninKebbi | 7.1658 | BirninKebbi | <mark>8.973</mark> | BirninKebbi |
| 3-1 | 8.5218 | JebbaTs | 3.1828 | Kainji | <mark>9.3828</mark> | Kainji |
| 4-3 | <mark>16.4165</mark> | Oshogbo | 3.2043 | JebbaTs | 5.615 | JebbaTs |
| 5-3 | 10.3361 | JebbaTs | 3.7182 | Kainji | 3.7935 | JebbaTs |
| 6-5 | <mark>11.4695</mark> | Papalanta | 3.5445 | Ayede | 5.831 | Ayede |
| 7-6 | <mark>7.5392</mark> | Akangba | 1.4389 | Papalanto | 3.2273 | Ikeja West |
| 8-6 | <mark>12.0213</mark> | Papalanto | 3.5589 | Ayede | 5.6907 | Ayede |
| 8-7 | <mark>7.6034</mark> | Papalanto | 1.0787 | Osogbo | 3.6238 | Ayede |
| 8-5 | <mark>23.9129</mark> | Ikeja West | 6.2204 | Papalanto | 10.541 | Papalanto |
| 8-9 | <mark>12.4105</mark> | Egbin | 4.6204 | Akangba | 7.3992 | Akangba |
| 10-8 | <mark>11.3709</mark> | Akangba | 3.3964 | Ikeja West | 5.3705 | Ikeja West |
| 10-11 | <mark>14.2855</mark> | Omotosho | 4.7743 | Aja | 7.8635 | Aja |
| 12-8 | 2.1338 | Sapele | <mark>8.3932</mark> | Ajaokuta | 8.3932 | Benin |
| 12-13 | 4.3169 | Benin | <mark>4.4479</mark> | Omotosho | 4.3787 | Ajaokuta |
| 13-10 | <mark>9.7498</mark> | Aja | 7.7994 | Ajaokuta | 7.7994 | Benin |
| 13-8 | <mark>4.2561</mark> | Akangba | 1.0363 | Ikeja West | 3.6871 | Omotosho |
| 13-5 | 9.256 | Ayede | <mark>12.3477</mark> | Ajaokuta | 12.3477 | Benin |
| 13-18 | 9.8673 | Sapele | 13.8204 | Sapele | <mark>22.6256</mark> | Sapele |
| 14-13 | 7.1047 | Aja | 10.776 | Ajaokuta | 10.7761 | Benin |
| 15-13 | 2.6304 | Ajaokuta | 8.2326 | Ajaokuta | <mark>8.23255</mark> | Benin |
| 15-17 | 5.4213 | Aja | 3.4523 | Sapele | <mark>24.0364</mark> | Aladja |
| 16-13 | 4.6151 | Aladja | 8.6404 | Aladja | <mark>21.9803</mark> | Aladja |
| 16-17 | 1.5931 | Aja | <mark>7.9062</mark> | Aladja | 5.8227 | Benin |
| 18-20 | 7.0294 | New Haven | 10.6699 | New Heaven | <mark>15.7524</mark> | Okpai |
| 19-18 | 2.5873 | Benin | 2.5873 | Benin | <mark>4.1100</mark> | Alaoji |
| 21-22 | 3.8533 | Onitsha | 5.7873 | Ajaokuta | <mark>6.8982</mark> | Onitsha |
| 22-18 | 10.8159 | Alaoji | 13.9714 | Alaoji | <mark>25.4175</mark> | Alaoji |
| 23-3 | 4.1506 | JebbaTs | 2.496 | Shiroro | <mark>5.2994</mark> | Shiroro |
| 23-24 | 3.5248 | Katampe | 5.5056 | Katampe | 7.45595 | Katampe |
| 23-25 | 5.1388 | Kaduna | 5.1385 | Kaduna | <mark>9.67325</mark> | Kaduna |
| 25-26 | 4.8543 | Kano | 6.7731 | Kano | 7.7021 | Kano |
| 25-27 | 4.386 | Jos | 6.3477 | Jos | <mark>7.695</mark> | Jos |
| 27-28 | 2.9706 | Gombe | 4.022 | Gombe | <mark>4.552</mark> | Gombe |

Note: Black = Low current (LC), Blue = Medium current (MC); Yellow = High Current (HC)

Table 3.4: Maximum line current caused by SLG, LL, DLG and Location when $Z_f = j0$

| From - To bus | SLG (pu) | Location | L - L (pu) | Location | DLG (pu) | Location |
|---------------|----------|-------------|------------|-------------|----------|-------------|
| 1-2 | 5.7715 | BirninKebbi | 8.0049 | BirninKebbi | 8.521 | BirninKebbi |
| 3-1 | 7.638 | Kainji | 8.6994 | Kainji | 9.9115 | Kainji |
| 4-3 | 11.8103 | JebbaTs | 15.5621 | JebbaTs | 16.6508 | JebbaTs |
| 5-3 | 6.7635 | Osogbo | 9.876 | Osogbo | 10.3859 | Osogbo |
| 6-5 | 8.0217 | Ayede | 10.7309 | Ayede | 11.4168 | Ayede |
| 7-6 | 5.0456 | Ikeja West | 7.2605 | Ikeja West | 7.5195 | Ikeja West |
| 8-6 | 8.4356 | Ayede | 11.1363 | Ayede | 11.921 | Ayede |
| 8-7 | 4.6136 | Ayede | 7.2019 | Ayede | 7.4139 | Ayede |
| 8-5 | 16.4218 | Papalanto | 22.3493 | Papalanto | 23.6863 | Papalanto |
| 8-9 | 8.5826 | Akangba | 11.5117 | Akangba | 12.184 | Akangba |
| 10-8 | 8.4808 | Ikeja West | 10.8965 | Ikeja West | 11.4524 | Ikeja West |
| 10-11 | 9.4079 | Aja | 13.2802 | Aja | 13.962 | Aja |
| 12-8 | 6.5397 | Omotosho | 8.2427 | Benin | 8.5784 | Benin |
| 12-13 | 7.0578 | Benin | 5.981 | Omotosho | 6.5929 | Omotosho |
| 13-10 | 6.4179 | Egbin | 9.3047 | Egbin | 9.759 | Egbin |
| 13-8 | 2.9694 | Ikeja West | 4.0802 | Ikeja West | 4.270 | Ikeja West |
| 13-5 | 6.2546 | Osogbo | 8.7459 | Osogbo | 9.2419 | Osogbo |
| 13-18 | 16.4639 | Sapele | 24.5083 | Sapele | 25.4906 | Sapele |
| 14-13 | 7.2072 | Benin | 10.4319 | Benin | 10.8361 | Benin |
| 15-13 | 5.590 | Benin | 7.9602 | Benin | 8.2957 | Benin |
| 15-17 | 15.7491 | Aladja | 22.8129 | Aladja | 23.8742 | Aladja |

| 16-13 | 14.4491 | Aladja | 20.8551 | Aladja | 21.8356 | Aladja |
|-------|---------|---------|---------|---------|---------|---------|
| 16-17 | 1.5684 | Sapele | 3.2814 | Sapele | 2.9961 | Sapele |
| 18-20 | 10.5221 | Okpai | 14.2337 | Okpai | 17.5902 | Okpai |
| 19-18 | 2.79635 | Alaoji | 3.83995 | Alaoji | 4.18085 | Alaoji |
| 21-22 | 5.362 | Onitsha | 6.6105 | Onitsha | 6.83945 | Onitsha |
| 22-18 | 17.3628 | Alaoji | 24.1392 | Alaoji | 23.7693 | Alaoji |
| 23-3 | 5.7098 | JebbaTs | 7.9588 | JebbaTs | 4.19125 | JebbaTs |
| 23-24 | 4.77465 | Katampe | 6.762 | Katampe | 7.10515 | Katampe |
| 23-25 | 7.0505 | Kaduna | 8.9056 | Kaduna | 9.29395 | Kaduna |
| 25-26 | 5.3429 | Kano | 7.1218 | Kano | 7.4349 | Kano |
| 25-27 | 5.1403 | Jos | 6.893 | Jos | 7.3189 | Jos |
| 27-28 | 3.2031 | Gombe | 4.1324 | Gombe | 4.386 | Gombe |

Red = Available maximum current (AMC)

3.3. Evaluation of Technical Power Loss on the Power Line Test System

Here, the calculation of technical power losses is carried out on the power line test system i.e the Nigerian 330-kV transmission system, using the results obtained in tables3.3 and based on the established peak line currents for both average (LC/MC) and maximum (HC/AMC) line current magnitudes.

Typical Base Values at 100MVA Base for the Nigerian 330-kV System

$$V_b = \frac{V_L}{\sqrt{3}} = \frac{330 \times 10^3}{\sqrt{3}} = 190.5255kV$$
$$I_b = \frac{MVA_b}{3V_b} = \frac{100 \times 10^6}{3 \times 190.5255 \times 10^3}$$
$$= 174.9546A \text{ or } 0.175kA$$

$$R_b = \frac{V_b}{I_b} = \frac{190.5255 \times 10^3}{174.9546} = 1089\Omega$$

Using the above base values, the pu line current magnitude and line resistance are converted to their actual values. Thus, the power losses for LC, MC, HC and AMC are computed using equation 3.1.

$$P = I^2 R....(3.1);$$

The power losses for the various categories are calculated. Therefore, these power losses in the power line test system for LC, MC, HC and AMC are presented as 146.73MW, 323.24MW, 737.79 and 738.77MW respectively. The graphical representations of the power losses calculated for LC, MC, HC and AMC are shown in figure 3.2.



It can be seen in figure 3.2, that the equality of HC and AMC is confirmed and that is a justifiable approximation of equality. Therefore, the average of the HC and AMC which is 738.28MW is considered as the possible available peak loss in the power line test system. Now for this study, there are three categories of power loss level determined to be associated with the power line test system. These are;

- Low power line loss is146.73MW obtained from LC
- Medium power line loss is **323.24MW** obtained from MC
- High power line loss is**738.28MW** obtained from HC/AMC

The three power loss level scenarios are likened to the trio of steady-state, sub transient and transient situation.stages of a fault.

3.4. Annual Loss Estimation of Low, Medium and High Power Line Losses

Estimation of annual power line losses of the test system is carried out based on the results of the three power loss levels shown in figure 3.2above. Since these results are obtained at their maximum peak current, there is the necessity to have the knowledge of the test system daily peak demand or peak load in order to determine the actual point of peak demand which is part of the parameter needed to calculate the annual power line losses. It should be noted that the maximum demand or peak demand dictates the size of transmission lines for utilities even if that amount lasts just one hour per year [12]. The peak load data for the period (January 2013 – December 2013) are tabulated as shown in table 3.5. The data are inputted

into the HOMER simulation software [13]. Figure 3.4 shows the hourly average load variation for the Nigerian 330-kV transmission lines (test system). The peak load of

4950MW is as indicated in figure 3.3 and the daily average energy of 3754.69MW is computed from table 3.5.

 Table 3.5: Daily peak demand of the test transmission system (January 2013–Dec. 2013)

| Hour | 1/1/2013 | 1/2/2013 | 1/3/2013 | 1/4/2013 | 1/5/2013 | 1/6/2013 | 1/7/2013 | 1/8/2013 | 1/9/2013 | 1/10/2013 | 1/11/2013 | 1/12/2013 |
|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|
| 0.00-1.00 | 4200.00 | 3900.00 | 4050.00 | 4200.00 | 4120.00 | 3700.00 | 3800.00 | 3700.00 | 3250.00 | 3425.00 | 3200.00 | 3450.00 |
| 1.00-2.00 | 4300.00 | 4350.00 | 4100.00 | 4350.00 | 3650.00 | 3600.00 | 3650.00 | 3450.00 | 3500.00 | 3200.00 | 3650.00 | 3650.00 |
| 2.00-3.00 | 4310.00 | 4200.00 | 4200.00 | 4170.00 | 3000.00 | 3700.00 | 3700.00 | 3250.00 | 3550.00 | 3275.00 | 3550.00 | 3500.00 |
| 3.00-4.00 | 4950.00 | 4150.00 | 4300.00 | 4100.00 | 2800.00 | 3775.00 | 3600.00 | 3500.00 | 3725.00 | 3175.00 | 3650.00 | 3400.00 |
| 4.00-5.00 | 3850.00 | 4250.00 | 4150.00 | 4050.00 | 3400.00 | 4100.00 | 3900.00 | 3575.00 | 3750.00 | 3400.00 | 3525.00 | 3500.00 |
| 5.00-6.00 | 3852.00 | 4170.00 | 4400.00 | 4100.00 | 3300.00 | 4025.00 | 4050.00 | 3600.00 | 3450.00 | 3500.00 | 3350.00 | 3450.00 |
| 6.00-7.00 | 4100.00 | 4120.00 | 4300.00 | 4070.00 | 3700.00 | 4025.00 | 3800.00 | 3900.00 | 3475.00 | 3400.00 | 3450.00 | 3300.00 |
| 7.00-8.00 | 4250.00 | 4200.00 | 4250.00 | 4250.00 | 4000.00 | 3850.00 | 3750.00 | 3800.00 | 3350.00 | 3600.00 | 3750.00 | 2900.00 |
| 8.00-9.00 | 3550.00 | 4150.00 | 4150.00 | 4350.00 | 4100.00 | 4100.00 | 3900.00 | 3800.00 | 3375.00 | 3700.00 | 3650.00 | 2875.00 |
| 9.0 - 10.0 | 4200.00 | 4290.00 | 4175.00 | 4100.00 | 4050.00 | 3700.00 | 3700.00 | 4025.00 | 2600.00 | 3800.00 | 3550.00 | 2900.00 |
| 10.00- 11.00 | 4300.00 | 4230.00 | 4275.00 | 4150.00 | 3700.00 | 3900.00 | 3600.00 | 3800.00 | 2700.00 | 3825.00 | 3450.00 | 2875.00 |
| 11.00-12.00 | 4450.00 | 4250.00 | 4250.00 | 3900.00 | 4050.00 | 3700.00 | 3500.00 | 3000.00 | 3000.00 | 3600.00 | 3750.00 | 3400.00 |
| 12.00-13.00 | 4500.00 | 4200.00 | 4400.00 | 4150.00 | 4075.00 | 4025.00 | 3100.00 | 3300.00 | 3300.00 | 3475.00 | 3500.00 | 3450.00 |
| 13.00-14.00 | 4517.60 | 4050.00 | 4200.00 | 4250.00 | 4200.00 | 3750.00 | 3725.00 | 3200.00 | 3550.00 | 3550.00 | 3850.00 | 3700.00 |
| 14.00-15.00 | 4517.00 | 4250.00 | 4300.00 | 4100.00 | 3850.00 | 4200.00 | 3500.00 | 3750.00 | 3450.00 | 3300.00 | 3650.00 | 3200.00 |
| 15.00-16.00 | 4250.00 | 4270.00 | 4100.00 | 3600.00 | 3800.00 | 3600.00 | 3700.00 | 3000.00 | 3500.00 | 3350.00 | 3825.00 | 3475.00 |
| 16.00-17.00 | 4300.00 | 4150.00 | 4350.00 | 4100.00 | 4000.00 | 3200.00 | 3750.00 | 3200.00 | 3325.00 | 3250.00 | 3650.00 | 3400.00 |
| 17.00-18.00 | 4250.00 | 4200.00 | 4275.00 | 4150.00 | 3700.00 | 3300.00 | 3675.00 | 3175.00 | 3275.00 | 3500.00 | 3700.00 | 3450.00 |
| 18.00-19.00 | 4220.00 | 4150.00 | 4250.00 | 3850.00 | 3900.00 | 3300.00 | 2500.00 | 3200.00 | 3500.00 | 3100.00 | 3450.00 | 3500.00 |
| 19.00-20.00 | 4150.00 | 4250.00 | 4250.00 | 3600.00 | 4000.00 | 3525.00 | 3600.00 | 3300.00 | 3400.00 | 3150.00 | 3750.00 | 3550.00 |
| 20.00-21.00 | 4300.00 | 4200.00 | 4300.00 | 4100.00 | 3750.00 | 3700.00 | 3525.00 | 3500.00 | 3375.00 | 3200.00 | 3900.00 | 3600.00 |
| 21.00-22.00 | 4125.00 | 4025.00 | 4225.00 | 4000.00 | 3800.00 | 3650.00 | 3600.00 | 3450.00 | 3350.00 | 3275.00 | 3600.00 | 3700.00 |
| 22.00-23.00 | 4100.00 | 4100.00 | 4275.00 | 4100.00 | 4050.00 | 3600.00 | 3675.00 | 3350.00 | 3375.00 | 3250.00 | 3350.00 | 3750.00 |
| 23.00-0.00 | 3900.00 | 4050.00 | 4200.00 | 4120.00 | 3700.00 | 3800.00 | 3700.00 | 3250.00 | 3425.00 | 3200.00 | 3450.00 | 3300.00 |



Figure 3.3: The daily peak demand load (January 2013 – December 2013)



Figure 5: The monthly average load plot (January 2013 – December 2013)

From the result obtained in the simulation of peak load and average load under peak transmission line (test system) for January 2013 – December 2013, the total loss is obtained as follows: The daily load factor is given based on hourly load reading as

Daily load Factor (DLF) = $\frac{Average \ load \ in \ 24h}{Peak \ load \ in \ 24h} 3.2$

Load factor may be given for a day, a month, or a year. The yearly or annual LF is the most useful since a year represents a full cycle of time. Thus, the annual LF is given as

Annual load Factor (ALF) =
$$\frac{total annual energy}{Peak load \times 8760 hr} 3.3$$

In this study, the annual load factor (ALF) is estimated from the average load by using the hourly average load variation for January 2013 – December 2013.

3.6

Thus, the ALF is obtained as

 $ALF = DLF \times R_{AD} \times R_{AM} [14] 3.4 3.4$

Where

ALF = Annual Load Factor

DLF = Daily load Factor

$$R_{AD} = \frac{Average \ daily \ peak \ load}{Mont \ hly \ Peak \ load} 3.5$$

 $R_{AM} = \frac{Average monthly peak load}{Annual Peak load}$

From the hourly readings of table 6, the peak load is 4950MW as indicated in figure 4 and daily average load is 3754.69 as calculated from table 3.5

Using equation 3.2 above, DLF is

$$DLF = \frac{Average \ load \ in \ 24h}{Peak \ load \ in \ 24h} = \frac{3754.69}{4950} = 0.759$$

The average daily peak load for January – December 2013 is 3812.08MW with monthly peak load of 4950MW in January.

Thus, using equation 3.5

$$R_{AD} = 3812.08/4950 = 0.770$$

Also from figure 3.4,

The average monthly peak load = 4400MW and the annual peak load = 4950MW.

Thus, using equation 6; $R_{AM} = 4400/4950 = 0.889$

Therefore, using equation 4.3, annual load factor (ALF) is given as

 $ALF = 0.759 \times 0.770 \times 0.889 = 0.52$

The Load Loss Factor (LLF) required for annual energy calculation is given as

 $LLF = K \times ALF + (1-K) \times (ALF)^2$ [15] 3. 7

where K means proportioning multiplier in the LLF equation 7;

where $0 \le K \le 1$ and K is normally 0.3 for transmission line.

Volume 5 Issue 1, January 2016 <u>www.ijsr.net</u> Licensed Under Creative Commons Attribution CC BY Using equation 3.7;

LLF = $0.3 (0.52) + 0.7 (0.52)^2 = 0.345$

Using the Loss Load Factor (LLF) of 0.345, the annual energy for the three categories of power loss evaluated in this study can be estimated as

➤ Annual MWH Loss for 146.73MW (Low Power Loss Level):

= LLF × (peak loss in MW) × 8760. 3. 8

Using the maximum power loss of 146.73MW obtained in the course of this work; the total energy loss for year 2013 is estimated as

= 0.345 × 146.73 × 8760 = 443447.41MWH or 443.45GWH

➤ Annual MWH Loss for 323.24MW (Medium Power Loss Level):

Using equation 8 and the maximum power loss of 323.24MW obtained in the course of this work as medium power loss level; the total energy loss for the year 2013 is estimated as

= 0.345 × 323.24 × 8760 = 976895.93MWH or 976.895GWH

> Annual MWH Loss for 738.28MW (High Power Loss Level):

Using equation 8 and the maximum power loss of 738.28MW obtained in the course of this work as high power loss level; the total energy Loss for the year 2013 is estimated as

= 0.345 × 738.28 × 8760 = 2231229.82MWH or 2231.230GWH

3.5. Cost Implications

The total amount of financial loss in the estimated annual energy loss of section 3.4 is evaluated for each of the power loss levels – Low, Medium and High power losses. The cost evaluation is based on the Naira/KWH energy rates for Eko district, under the new power tariff MYTO 2 for 2013/2014 [16]. The cost of energy is rated at N19 per KWH or N19000/MWH, by taking the average of all the tariff class energy unit costs (N/KWH). Using the N19000/MWH, the annual financial loss due to each power loss level associated with the 330-kV power lines is estimated as follows:

- ➢ For the Low Power Line Loss with annual loss of 443447.41MWH, the annual financial loss for the year 2013 is 443447.41MWH ★ N19000/MWH
- i.e. N8, 425,500,790; approximately amounted to **8.4** billion Naira

- ➢ For the Medium Power Line Loss with annual loss of 976895.93MWH, the annual financial loss for the year 2013 is 976895.93MWH × N19000/MWH
- i.e. N1.86 $\times 10^{10}$; approximately amounted to18.6 billion Naira
- ➢ For the Low power line loss with annual loss of 2231229.82MWH, the annual financial loss for the year 2013 is 2231229.82MWH × N19000MWH

i.e. N4.24 \times 10¹⁰; approximately amounted to **42.4 billion** Naira

4. Conclusion

In this study, the evaluation of technical losses-steady and transient phenomena was captured successfully on Nigeria 330-kV transmission network. Three levels (i.e low, medium and high) of maximum line current were determined and used accordingly to calculate the three categories of power loss level associated with the network which in turn was used to estimate the annual power line losses for the year 2013 using the peak load data for the period (January2013 - December2013). The annual loss energy for the year 2013 and the huge financial drain in the network were identified and quantified; the low, medium and high energy losses were respectively found to 443.45GWH. 976.895GWH be and 2231.230GWHamounting to financial losses of N8.4 billion, N18.6 billion and N42.4 billion respectively.

The results of the load-flow analysis that were performed using MATLAB and PWS compared favourably well with the 146.73MW power loss obtained at steady-state in this work. Also, it validated the results of 2231.23GWH losses obtained in the work with the normal practice of PHCN energy balance (as shown in table 2.1)thereby closing the gap between the practical information and the theoretical one and also it optimizes the loss level which results in a high degree of accuracy.

Acknowledgement

The author is highly indebted to Power Holding Company of Nigeria (PHCN) for providing relevant data necessary for power-flow study and the peak load demand data for the period (January 2013-December 2013.

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