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# Assessment of Reliability Indices of Abuja Distribution Network

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**Abstract— Assessment of customer power supply reliability is an important part of distribution system operation and planning. Analysis of outage data from a practical distribution system is performed in order to assess the reliability indices. The aim of this paper is to assess the reliability and analysis customer power supply of Abuja metropolis, evaluating with SAIDI, SAIFI and CAIDI. The report consists of measuring past performance, including reliability indices; sources of data; and existing methods for reliability analysis. The main conclusion of the report is that, Abuja municipal city reliability network measured failed below the average industrial city: SAIDI, 392.88 hrs of duration in 2007, CAIDI, 1.82 hrs while SAIFI records 215.47.**

***Keywords— Reliability, Distribution system reliability, Availability, Failure and Reliability indices.***

## I. INTRODUCTION (*Heading 1*)

Reliability concerns are often split into three categories: Adequacy, Security and Quality. Adequacy is the capacity and energy to meet demand; Security is the ability to withstand disturbances; and Quality is the acceptable frequency, voltage and harmonic characteristics. There are more than forty reliability indices, the most common one include SAIDI, SAIFI, CAIDI, MAIFI, ASAI etc, other common indices that measure unavailability include ASUI which is complement of ASAI, EENS, and AENS. The indices used in this report are SAIDI, SAIFI and CAIDI [1]. These indices are generallyyearly average of interruption of frequency and duration. They attempt to capture the magnitude of disturbances by load lost during each interruption. We used these indices; CAIDI, SAIFI and SAIDI method because there were best suited to the subject discussed. These reliability indices are among the following.

1. *Customer Average Interruption Duration Index* (CAIDI) is an indicator of average interruption duration, or the time to restore service to interrupted customers.
2. *System Average Interruption Frequency Index* (SAIFI) is an indicator of average service interruption frequency experienced by customers on a system.
3. *System Average Interruption Duration Index* (SAIDI) is a composite indicator of outage frequency and duration and is calculated by dividing the customer minutes of interruptions by the number of customers served on a system. Mathematically, SAIDI is the product of SAIFI and CAIDI. Thus, a SAIDI of 100 may be achieved by a SAIFI of 1 and a CAIDI of 100, or by a SAIFI of 1.25 and a CAIDI of 80

## II. RELIABILITY STUDIES OF ABUJA DISTRIBUTION NETWORK



The power system is vulnerable [2] to system abnormalities such as control failures, protection or communication system failures, and disturbances, such as lightning, and human operational errors. Therefore, maintaining a reliable power supply is a very important issue for power systems design, operation and planning [3]. The results of reliability assessment of distribution systems supplying electricity of various consumers in Abuja Federal Capital Territory are presented and discussed. The various reliability indices computed for the distribution systems in all the districts of Abuja Federal Capital Territory are based on the methodology described. The major causes of power supply problems in Abuja have been identified and also summarized in Tables 1 to 4. There are a number of problems associated with transmission, distribution and consumption of electricity in a rural area. A study into the problems of power supply shows that disturbance on the commercial mains power supply can be categorized into the following: (i) Weather problem, (ii) Human problem and (iii) Planned problem. The computed annual outages and their durations between 2002 and 2007 according to fault type are given in Table 1.

Table1: outage and duration of faults types for the Abuja distribution network, 2002 – 2007 (Okorie, 2009)

| S/N | Nature & causes of fault due to bad joint | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | | Avg. outage & duration /year | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Freq. | Duration | Freq. | Duration | Freq. | Duration | Freq. | Duration | Freq. | Duration | Freq. | Duration | Freq. | Duration |
| 1 | UG cable | 120 | 158.74 | 87 | 224.38 | 142 | 280.46 | 56 | 305.79 | 176 | 545 | 98 | 381.16 | 113.2 | 315.92 |
| 2 | Cable sparked by diggers | 5 | 45.61 | 5 | 38.12 | 5 | 38.34 | 4 | 55.45 | 6 | 51.37 | 2 | 14.35 | 4.5 | 40.54 |
| 3 | Pole and equipment damaged by vehicles | 28 | 176.82 | 35 | 130.23 | 31 | 234.34 | 27 | 237.6 | 79 | 379.3 | 17 | 241.23 | 36.2 | 233.25 |
| 4 | Failure of line due to jumper or cross arm | 1079 | 558.1 | 286 | 476.6 | 472 | 331.04 | 349 | 454.81 | 551 | 720.3 | 422 | 804.82 | 526.5 | 557.6 |
| 5 | Tree falling on line | 171 | 218.91 | 21 | 105.28 | 56 | 262.13 | 78 | 218.5 | 52 | 295.5 | 55 | 338.99 | 72.2 | 239.88 |
| 6 | Faulty transformer | 32 | 374.6 | 11 | 253.37 | 26 | 435.32 | 33 | 261.13 | 30 | 426.6 | 9 | 590.36 | 23.5 | 390.23 |
| 7 | Faulty switchgear/panel | 10 | 69.54 | 19 | 54.02 | 20 | 86.12 | 29 | 116.41 | 37 | 98.74 | 16 | 105.97 | 21.8 | 88.47 |
| 8 | Faulty tripping unit | 151 | 138.06 | 54 | 124.79 | 165 | 110.43 | 30 | 53.72 | 95 | 269.6 | 6 | 15.73 | 83.5 | 118.72 |
| 9 | Earth fault | 938 | 231.53 | 441 | 209.08 | 1689 | 756.4 | 2235 | 822.86 | 805 | 1467 | 1178 | 1478.3 | 1241.3 | 827.57 |
| 10 | Over current | 846 | 226.36 | 342 | 254.04 | 1328 | 498.93 | 1750 | 702.7 | 785 | 573.8 | 1197 | 1070.9 | 1041.3 | 554.48 |
| 11 | Other causes | 219 | 274.02 | 40 | 168.96 | 80 | 382.53 | 156 | 364.13 | 119 | 336.6 | 232 | 851.38 | 141 | 396.26 |
| 12 | Yearly total | 3599 | 2472.3 | 1341 | 2038.87 | 4014 | 3416 | 4747 | 3593.1 | 2735 | 5164 | 3232 | 5893.2 | 3278 | 3762.91 |



## III. Reliability Indicators For Measuring Service Quality Performance Modeling

These are the five key reliability indicators recently introduced for the purpose of assessing distribution reliability performance. These are the reliability indices used by the Florida's Investor –owned electric utilities (IOU) for assessing and auditing their performance in electricity distribution system [5]. Such reliability indicators are listed below:

i. Customer Average Interruption Duration Index (CAIDI);

ii. System Average Interruption Frequency Index (SAIFI);

iii. System Average Interruption Duration Index (SAIDI);

iv. Momentary Average Interruption Event Frequency Index/Indicator (MAIFI);

v. Customers Experience More than Five Interruptions (CEMI5).

The mathematical computation is as follows:

$$CAIDI_{ik} = \frac{Sum\ of\ all\ customers\ minutes\ interrupted\ (CMI_{ik})}{Total\ number\ of\ customers\ interruptions\ (CI_{ik})} \quad (1)$$

$$SAIFI_{ik} = \frac{Total\ number\ of\ customer's\ interruption\ (CI_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})} \quad (2)$$

$$SAIDI_{ik} = \frac{Sum\ of\ all\ customers\ minutes\ interrupted\ (CMI_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})} \quad (3)$$

$$MAIFIE_{ik} = \frac{Sum\ of\ all\ customers\ momentary\ interruption\ events\ (CME_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})} \quad (4)$$

$$CEMI5_{ik} = \frac{Customers\ experienced\ more than\ 5\ interruptions\ (CEM5_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})}\ x\ 100\%$$

5

i = 1, 2, 3 ………………………… m
k = 1, 2, 3 ………………………… n
wherei denotes year and
k denotes $k^{th}$ district

These five performance indices express interruption statistics in terms of system customers. A customer here can be either feeder, or an individual, firm, or organization who purchases electric services at one location under one rate classification, contract or schedule. If service is supplied to a customer at more than one location, each location shall be counted as a separate customer. Furthermore, the well known basic reliability indices are defined in equations ( 6 ) to ( 12 ).

$$\text{Mean Time To Failure (MTTF)} = \frac{1}{Failure\ Rate} \quad (6)$$

$$\text{Mean Time To Repair (MTTR)} = \frac{Fault\ Duration}{No.\ of\ Outage} \quad (7)$$

$$\text{Mean Time Between Failure (MTBF)} = MTTF + MTTR \quad (8)$$

$$\text{Failure Rate } (\lambda) = \frac{1}{MTTF} \quad (9)$$

$$\text{Repair Rate } (\mu) = \frac{1}{MTTR} \quad (10)$$

$$\text{Availability} = \frac{\mu}{\lambda+\mu} \quad (11)$$

$$\text{Unavailability} = \frac{\lambda}{\lambda+\mu} \quad (12)$$

The computations of the above basic reliability indices required acquisition of fields data on distribution component failure statistics over the desired time frame.

## IV. ANALYSIS OF DATA COLLECTED USING RELIABILITY INDICES

Tables 2 to 4, and Figure 2 summarize the results of several reliability analysis carried out in respect of electricity supplied to the customers in Abuja municipal city and satellite towns from 2002 -2007. Herein, service reliability indices (Failure rate, MTTR, MTTF, MTBF, CAIDI, SAIDI and SAIFI) were computed for all the five districts and for each year of the study period using equations (1) to (12).

Table 2: Reliability indices of Abuja distribution network for the specified study period *[4]

| S/No | Parameters | Wuse District | Garki District | Kubwa District | Karu District | G/Lada District | Abuja Metropolis |
|---|---|---|---|---|---|---|---|
| 1 | Total no. of failure/outages | 5558 | 3676 | 552 | 1151 | 1091 | 19681 |
| 2 | Total outages duration | 4208.49 | 5003.99 | 1404.28 | 1890.71 | 2480.15 | 21496.88 |
| 3 | Average duration of outage (hrs/yr) (MTTR) | 1062.35 | 1252.21 | 703.34 | 945.36 | 1240.08 | 3582.81 |
| 4 | Failure rate | $158.618 \times 10^{-3}$ | $104.908 \times 10^{-3}$ | $31.507 \times 10^{-3}$ | $65.696 \times 10^{-3}$ | $62.215 \times 10^{-3}$ | $374.448 \times 10^{-3}$ |
| 5 | Mean Time To Failure (MTTF) | 6.322 | 9.532 | 31.739 | 15.222 | 16.073 | 2.671 |
| 6 | Mean Time Between Failure | 1068.85 | 1261.74 | 735.08 | 960.58 | 1256.15 | 3585.481 |
| 7 | Repair Time | $9.412 \times 10^{-4}$ | $7.986 \times 10^{-4}$ | $1.422 \times 10^{-4}$ | $1.058 \times 10^{-4}$ | $8.064 \times 10^{-4}$ | $2.791 \times 10^{-4}$ |

*study period for Wuse and Garki : 2004-2007;
Study period for Kubwa, Karu and G/Lada: 2006-2007;
Study period for Abuja Territorial District: 2002-2007.

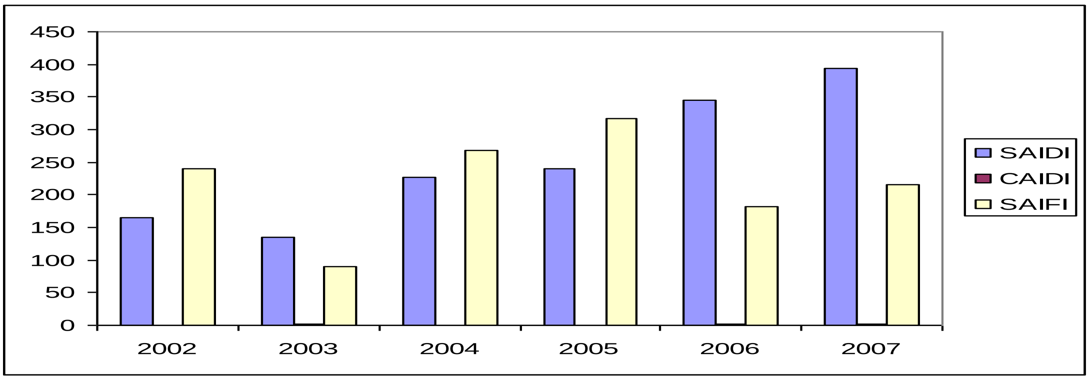


Figure 2: Abuja Municipal Network.Table3: Service reliability indices data year 2007

| Utility Name – ADC [4] | | | | | | | |
|---|---|---|---|---|---|---|---|
| District | Registered Customers Served (C) | Interruptions (N) | Total feeder hour of interruption (FHI) | Feeder Interrupted (FI) | SAIDI | CAIDI | SAIFI |
| Garki | 28,858 | 1164 | 2908886 | 2239381 | 100.80 | 1.30 | 77.60 |
| Wuse | 26,344 | 617 | 1494583 | 1083617 | 56.73 | 1.38 | 41.13 |
| Kubwa | 35,013 | 200 | 1489220 | 466840 | 42.53 | 3.19 | 13.33 |
| Karu | 41,104 | 802 | 3510623 | 2197908 | 85.41 | 1.60 | 53.47 |
| G/Lada | 31,023 | 466 | 941031 | 963781 | 30.33 | 0.98 | 31.00 |



Table 4: Summary of service reliability for Abuja 2002 – 2007 [4]

| Year | Registered Customers Served (c) | Interrupted (N) | Total feeder hour of interruption (FHI) | Feeder Interrupted (FI) | SAIDI | CAIDI | SAIFI |
|---|---|---|---|---|---|---|---|
| 2002 | 145,989 | 3599 | 24061907 | 35027627 | 164.82 | 0.69 | 239.9 |
| 2003 | 146,349 | 1341 | 19892439 | 13083601 | 135.92 | 1.52 | 89.4 |
| 2004 | 148,750 | 4014 | 33875333 | 39805500 | 227.73 | 0.85 | 267.6 |
| 2005 | 150,394 | 4747 | 36025379 | 47594688 | 239.54 | 0.76 | 316.47 |
| 2006 | 158,446 | 2735 | 54547676 | 28889987 | 344.27 | 1.89 | 182.33 |
| 2007 | 162,342 | 3232 | 63780925 | 34979290 | 392.88 | 1.82 | 215.47 |

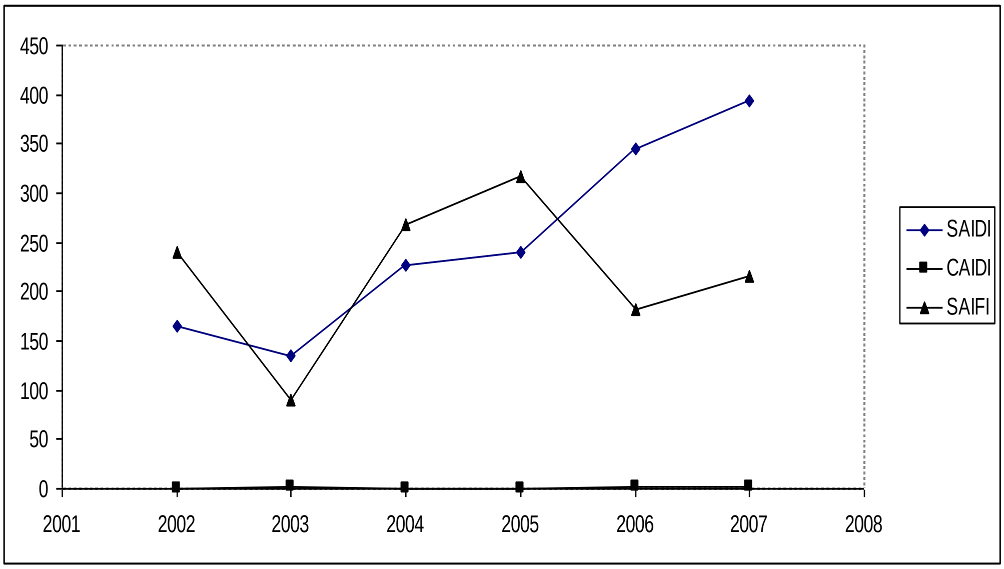


Figure 3: Abuja Municipal City Reliability Network Measured.

## V. RESULTS AND DISCUSSION

From Table 1 through 4 and Figures 2and 3, it can be seen that outages per feeder per year for all districts variedbetween (1341 to 4747). The Wuse feeders recorded the highest outage rates per feeder per year while the least is Kubwa feeder. However, Garki had the highest duration of outage account for 5003.99 hours. This records a total of about 209 days continuous `blackout`. This is followed by Wuse, which had 4208.49 hours duration of outage. This means a total of about 176 day's continuous blackout. The least is also Kubwa with 1404.28 hours, 59 days blackout. These values are far too high when compared to the typical 2% value for industrialized nations and accounts for much of the national operational problems in the supply of electric power. There is need to analyze problem in the supply of electrical power. There is further need to analyze the fault to identify reasons for the high level of unavailability of the feeders.

According to Table 1, several factors have been identified to be responsible for these outages. The major cause of outages is earth fault (earth leakage). The average outage frequency per year recorded is 1214.3 and accounted for 37.04% of the total failure. The time duration was 827.57 hours. The next major cause was over current due to surge which contributed about 31.77%. The duration of the outage association with this was 1041.3 hours. Other significant outages were due to jumper or cross arm 16.06%; other causes 4.3%, under ground cable fault 3% etc. The basic under line factor responsible for the poor performance, however, was poor maintenance and attitude to duty. The total number of forced and scheduled outages were recorded with other causes which accounted for only 4.3%. Maintenance which is the back bone of successful performance had not been properly carried out for the Abuja 33kV and 11kV distribution network. If the feeders were not adequately maintained, increases operational cost might be incurred even if there was no frequent system failure.

The year by year assessment showed that the performance of the station was best in 2003. However, this value fell below expectation. The outage frequency recorded in 2003 was 1341 failures with 2038.77 hours of no electricity. The worst year was 2005 which accounted for about 4,747 failures which resulted to 3594.10 hours.



## VI. CONCLUSION.

Reliability evaluations are an important and integral feature of the planning, designs and operation of all engineering systems. Engineers must not only appreciate the benefits obtained from reliability assessments, but also how much such assessments can be made. The study has presented a statistical method of determining the power system components` failure rates and the associated durations. The method adopted was found to be satisfactory and comparable with other standard methods. The reliability parameters obtained gave a true reliability picture of the network.

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