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STATISTICAL DATA ANALYSIS OF ABUJA DISTRIBUTION NETWORK

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Abstract

In this study, comprehensive performance evaluations of the distribution facility outlay in Abuja Federal Capital Territory (FCT), Abuja have been carried out, using well established reliability techniques. The study has become imperative due to paucity of research activities in this field to justify the need for the envisioned integration of distribution network information and remote control system. In the main, this research work seeks to investigate and quantify the major causes of power outages in Abuja distribution company territorial area coverage and to proffer pragmatic solutions to enhance its reliability and security. In pursuit of the cardinal objective of this research work, there is need to collect and build extensive data base in respect of the case study distribution network.. More precisely, the data collected cover the following critical information amongst others: date of fault, time of fault, duration of fault, nature and causes of fault etc. The computational techniques developed are set forth. Finally, the initial findings and results obtained are presented and discussed. As expected, the reliability metrics computed for Abuja fell far below extant benchmark indices for optimally managed modern distribution networks of developed countries.

Keyword : *Distribution, Reliability Assesment, Reliability Metrics and Abuja*

http://internationalpolicybrief.org/journals/international-scientific-research-consortium-journals/intl-jrnl-of-innovative-research-in-tech-basic-applied-sci-vol2-no1-Sept-2015

Background to the Study

One of the most serious challenges for power industry restructuring is to maintain power system reliability at an acceptable level and to promote the overall economic efficiency of the whole power industry (Wen et al, 2006). Because of inadequate investment in the power industry, especially in most developing economies exemplified by Nigeria, the electricity infrastructural outlay cannot meet the consumer demand at all times.

As a first milestone achievement, the entire Nigeria distribution system has been split into eleven distribution companies as shown in Figure 1. Abuja Distribution Company is one of the eleven distribution companies and was established to supply or distribute electricity to Abuja Federal Capital of Nigeria and the neighboring states, (Kogi, Niger and Nasarawa States, respectively). Considering the significance of Abuja Distribution Company to the nation's prosperity and security, emphasis should be placed on the enhancement of its reliability performance as well as improvement on the quality of electriity delivery to consumers. This is the main thrust of this research using Abuja Distribution Company as the case study.

Historically, Abuja District came in to existen in the early nineties as Abuja Special Duties Office, to meet the electricity needs of the Federal Capital Territory (FCT), Abuja only. It later metamorphosed into a larger entity known as Abuja Distribution zone, in 1997- 2004 as shown in Figure 2 as one of the electricity distribution zones of the defunct National Electric Power Authority, (NEPA). Its current geographical territorial coverage includes the Federal Capital Territory, Abuja and the contiguous states of Niger, Nasarawa, and Kogi (PHCN News, 2006).

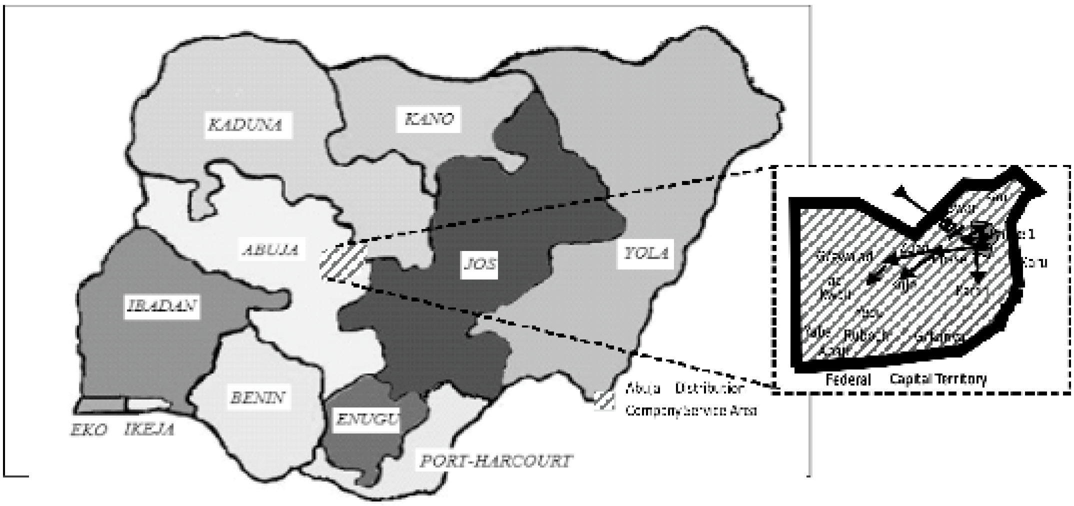


Figure 1: Geographical Service Area of the Nigeria Eleven Distribution Companies with Abuja Distribution

Company as the Case Study

Most electricity consumers are not satisfied with the reliability, security and quality of the electrical energy delivery from the national grid. Indeed, the cost of electrical energy not served by the utility, to both the utility and to electrical energy consumers in the Nigeria is estimated to run into several billions of Naira per annum (Sachchidanand, 2009). It is therefore of profound importance to investigate and characterize the major causes that underpin highly erratic electrical energy supply to various consumers. The knowledge of these technical problems will enable pragmatic solutions to be proffered from different viewpoints that include optimal distribution

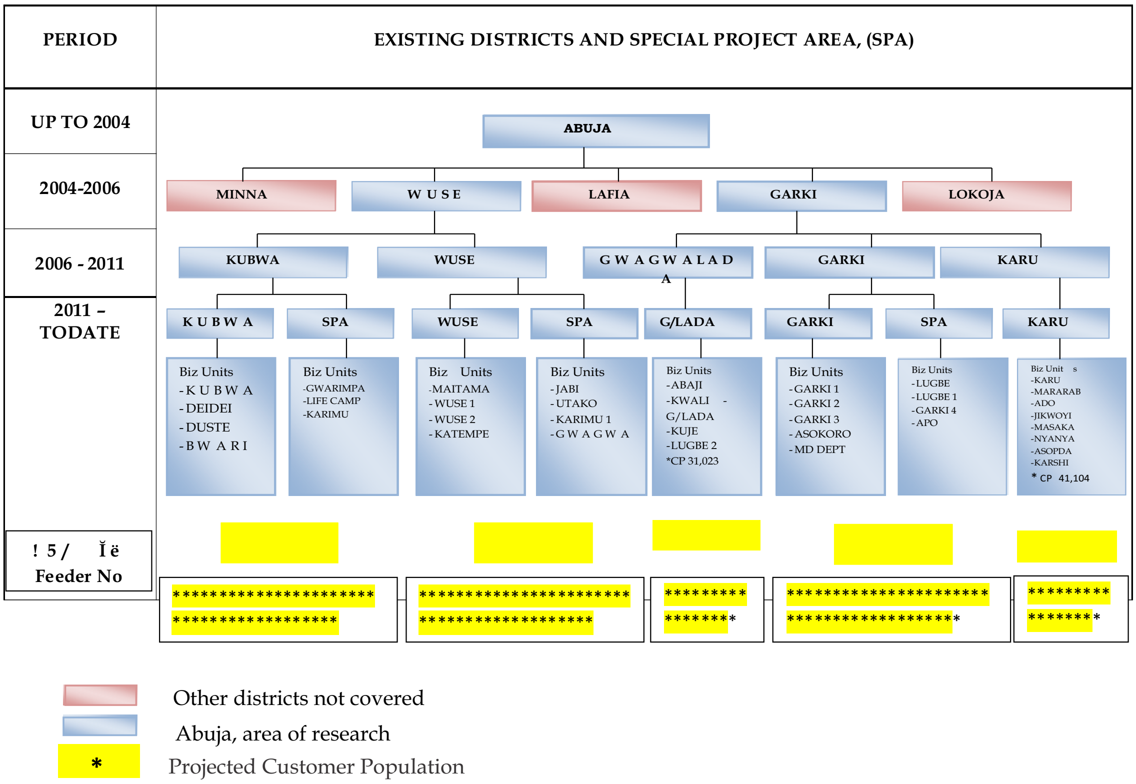


Figure 2: Evolution of electricity districts Abuja Metropolis

Network design, distribution automation and the emerging concept of self healing within cost effective architecture of smart distribution systems. The foregoing conceptual ideas constitute the main kernels of research challenges to be addressed in this work.

The aim of this research is to compute and analyze the reliability metrics for a typical distribution network with the view to identifying its critical operational problems that hamper efficient delivery of electrical energy to consumers. The main objective is to evaluate and develop a framework for reliability analysis of distribution system in Abuja. Towards the realization of this aim, the following objectives will be pursued:

1. Collection of field data covering a period of at least four years;
2. Determination of feeder reliability metrics;
3. Assessment of feeder outage frequency;
4. Characterization of feeder outage duration and their availability rates; and
5. Assessment of distribution transformers in Abuja environment.

Proposed Approach

This research is embarked upon in order to assess, compare and evaluate the reliability network of Abuja Distribution network amongst the other eleven existing distribution companies currently supplying electricity to various categories of consumers.

Generalized Computation of Reliability Metrics

Consider a distribution company service area split into n service areas having for each which relevant field data are available for m years. The generalized computational procedure of each reliability indicator is carried for

$$CAIDI_{ik} = \frac{Sumofallcustomersminutesinterrupted\ (CMI_{ik})}{Totalnumberofcustomerinterruptions\ (CI_{ik})} = \sum(r_{ik} * N_{ik}) / \sum(N_{ik}) \quad 1$$

$$SAIFI_{ik} = \frac{Totalnumberofcustomer's interruptions\ (CI_{ik})}{Totalnumberofcustomersserved\ (C_{ik})} = \sum(N_{ik})/N_{Tik} \quad 2$$

$$SAIDI_{ik} = \frac{Sumofallcustomersminutesinterrupted\ (CMI_{ik})}{Totalnumberofcustomersserved\ (C_{ik})} = \sum(r_{ik} * N_{ik})/N_{Tik} \quad 3$$

$$MAIFIE_{ik} = \frac{Sumofallcustomersmomentaryinterruptionevents\ (CME_{ik})}{Totalnumberofcustomersserved\ (C_{ik})} \quad 4$$

$$= \sum (ID_{ik} * N_{ik}) / N_{Tik}$$

$$= \frac{Customersexperiencingmorethan\ell interruptions\ (CEM\ell_{ik})}{Totalnumberofcustomersserved\ (C_{ik})} x100\% \quad 5$$

$$ASAI_{ik} = \frac{Totalnumberofcustomer'shoursavailable(CHA_{ik})}{Totalcustomershours'demanded\ (CHD_{ik})} \quad 6$$

$$= \left[1 - \left(\frac{\Sigma(r_{ik} * N_{ik})}{N_{Tik} * T_k}\right)\right] x100\%$$

$$CIII_{ik} = \frac{Totalnumberofcustomerinterruptions\ (CI_{ik})}{Numberofinterruptions\ (N_{oik})} \quad 7$$

$$= \sum (N_{ik}) / \sum (N_{oik})$$

$$CAIFI_{ik} = \frac{Totalnumberofcusomerinterruptions\ (N_{oik})}{Numberofcustomersaffected} \quad 8$$

$$= \sum (N_{oik}) / \Sigma(N_{ik})$$

$i = 1, 2, 3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots m$; and
$k = 1, 2, 3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots n$.

$$ENS_k = \sum_{i=1}^{m} kW_{ik} * T_{ik};\ k = 1, 2 \ldots\ldots n \quad 9$$

Where in eqns. 1-9, all the principal variables used are defined thus:

r_{ik} = Restoration time, hours;
N_{ik}=Total number of customers interrupted;
N_{Tik}= Total number of customers served;
T_k = Time period under study, hours;
ID_{ik}= Number of interrupting device operations;
N_{oik} = Number of interruptions; and

$kW_{ik} and T_{ik}$= Average demand and outage time for i^{th} service area at k^{th} year.

In this work, these key indicators have been employed extensively to assess the electricity distribution performance of the Abuja Distribution Company using field data collected from 2009 to 2012 as subsequently described. The detailed computational tasks embarked upon are underpinned by the following objectives:

1. To determine the statistics of physical structures of Abuja distribution network for the five districts currently supplying energy to Abuja metropolis over
2. To perform fault management on 33/11 kV power distribution lines;
3. To determine the causes of outages;
4. To determine the total percentage of failure
5. To determine the highest percentage of source failure contributed
6. To compute the entire feeder failure rate.
7. To assess overall availability performance.
8. Customer population projections for ADC districts.

The procedures adopted in this research for assessing the reliability of the distribution network in the Districts of Abuja Distribution Company are as follows:

1. Field data collection from the operations logbooks and data processing via available information packages;
2. Application of frequency and duration method to compute the distribution network outage rates, and outage probabilities;
3. Determination of the status of the equipment and to assess their parameters; and
4. Computation of reliability indices using standard reliability indicators.

The overall functional flowchart developed for this purpose is shown in Figure 3. It has been applied to compute the outage rates and their durations as well as outage probabilities.

Results of Field Data Analyses

The results of reliability assessment of distribution systems supplying electricity of various consumers in Abuja Federal Capital Territory are presented and discussed in this section. The various reliability indices computed for the distribution systems in all the districts of ADC are based on the methodology described in preceding section. The major causes of power supply disruptions in ADC have been identified and also summarized herein. Various pre-processed data are presented, Figure 4 depicts 3-D constructs of pre-processed data which detail all feeders (29 in number) monthly outage frequencies and Figure 5 similarly offers 3-D overview for the duration of each feeder outage.

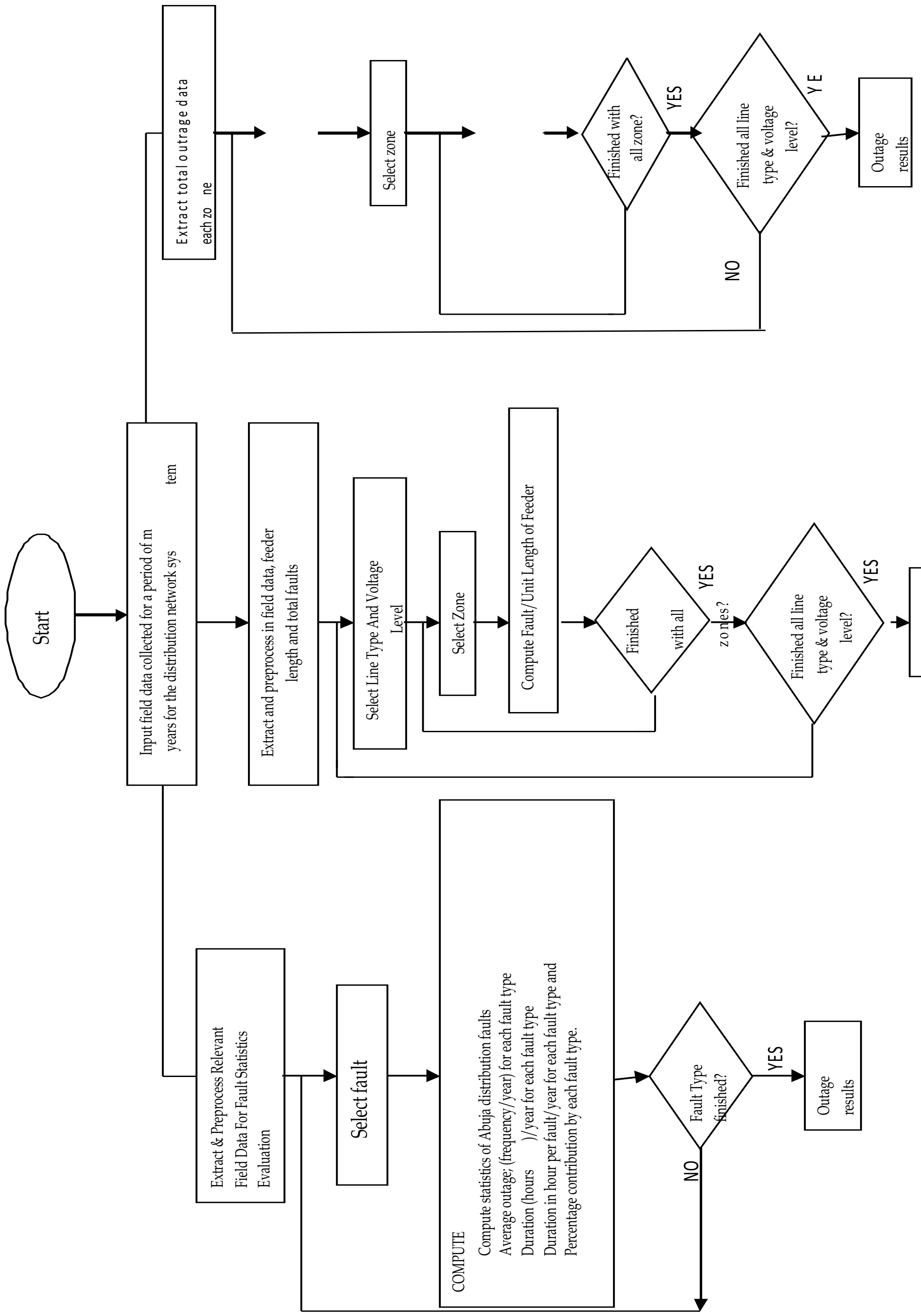
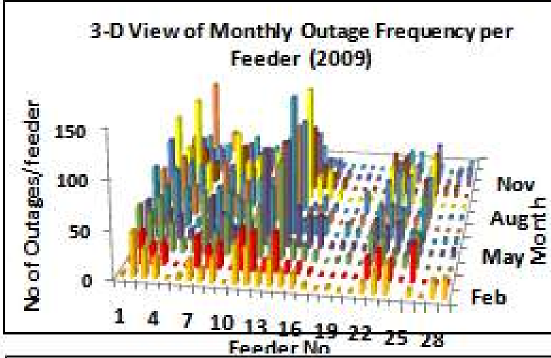
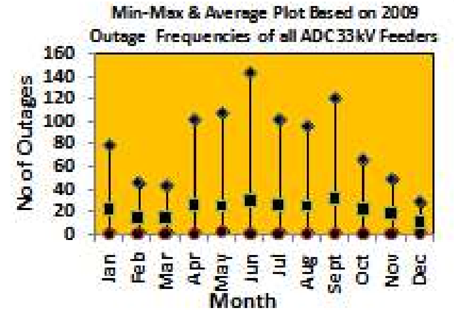
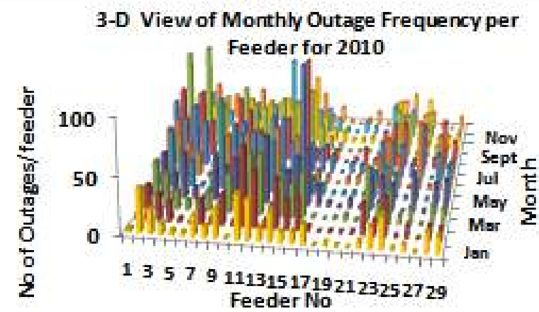
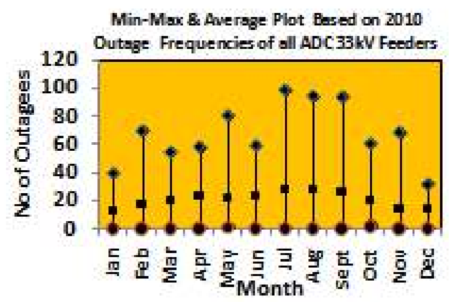


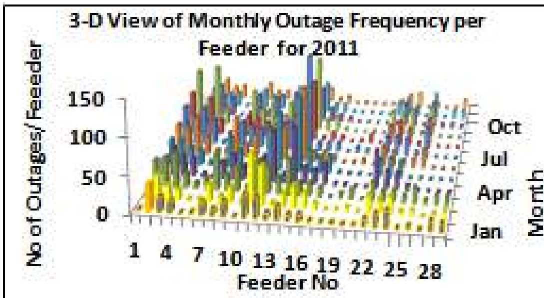
Figure 3: Overall Flowchart for Frequency and Duration Method

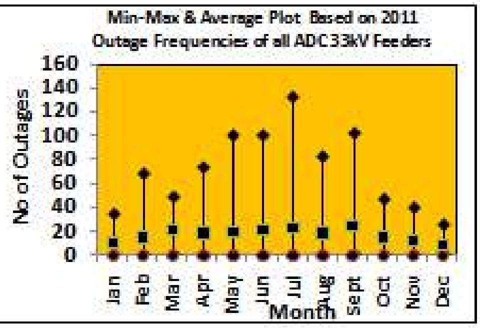

3-D View of Monthly Outage Frequency per Feeder (2009)
No of Outages/feeder
150
100
50
0
1 4 7 10 13 16 19 22 25 28
Feeder No
Nov
Aug
May
Feb
Month

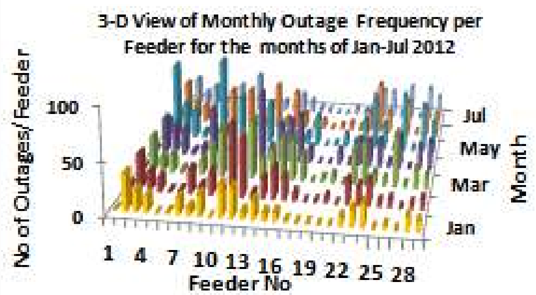

Min-Max & Average Plot Based on 2009 Outage Frequencies of all ADC 33kV Feeders
No of Outages
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month

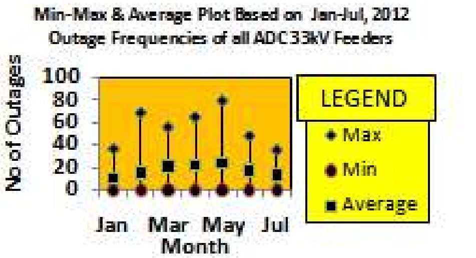

3-D View of Monthly Outage Frequency per Feeder for 2010
No of Outages/feeder
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Feeder No
Nov
Sept
Jul
May
Mar
Jan
Month


Min-Max & Average Plot Based on 2010 Outage Frequencies of all ADC 33kV Feeders
No of Outagees
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month


3-D View of Monthly Outage Frequency per Feeder for 2011
No of Outages/Feeeder
150
100
50
0
1 4 7 10 13 16 19 22 25 28
Feeder No
Oct
Jul
Apr
Jan
Month


Min-Max & Average Plot Based on 2011 Outage Frequencies of all ADC 33kV Feeders
No of Outages
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month


3-D View of Monthly Outage Frequency per Feeder for the months of Jan-Jul 2012
No of Outages/Feeder
100
50
0
1 4 7 10 13 16 19 22 25 28
Feeder No
Jul
May
Mar
Jan
Month


Min-Max & Average Plot Based on Jan-Jul, 2012 Outage Frequencies of all ADC 33kV Feeders
No of Outages
100
80
60
40
20
0
Jan Mar May Jul
Month
LEGEND
Max
Min
Average

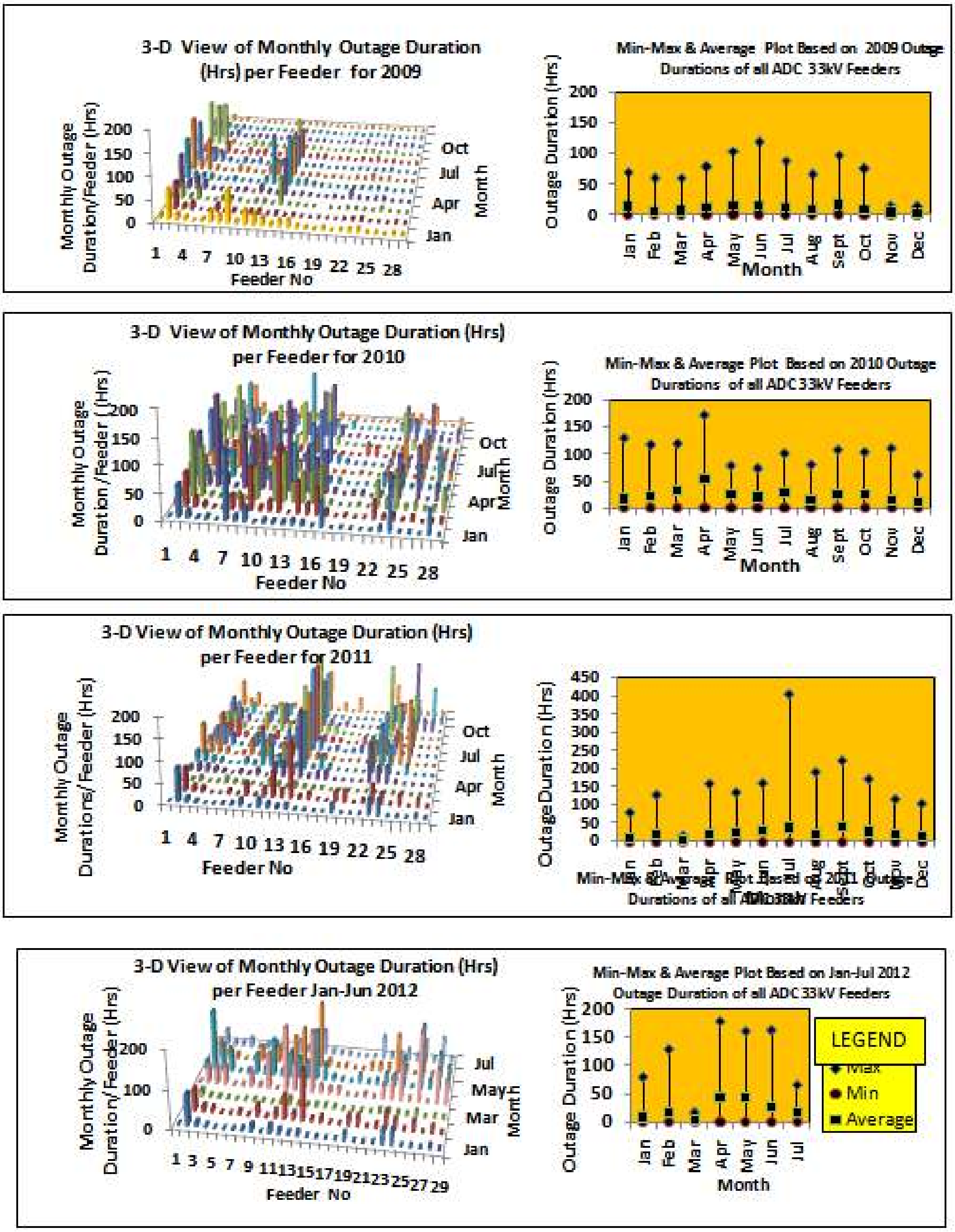


Figure 5: 3-D and Statistical Descriptions of ADC Feeder Outage Duration Data 2009-2012.

ADC feeder reliability metrics results

Relying on the algorithmic flowchart of Figure 3 and the results of processed field data presented in the preceeding section, we have computed some fundamental reliability metrics which are presented comprehensively in Figures 6 and 7. Table 1 summarizes benchmark reliability metrics computed for all ADC 33kV feeders with respect to the study period.

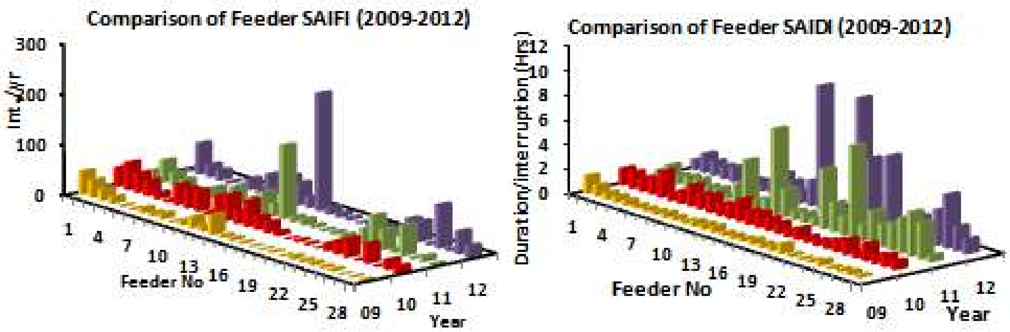


Figure 6: Comparative 3-D View of SAIFI and SAIDI for ADC Feeders (2009-2912)

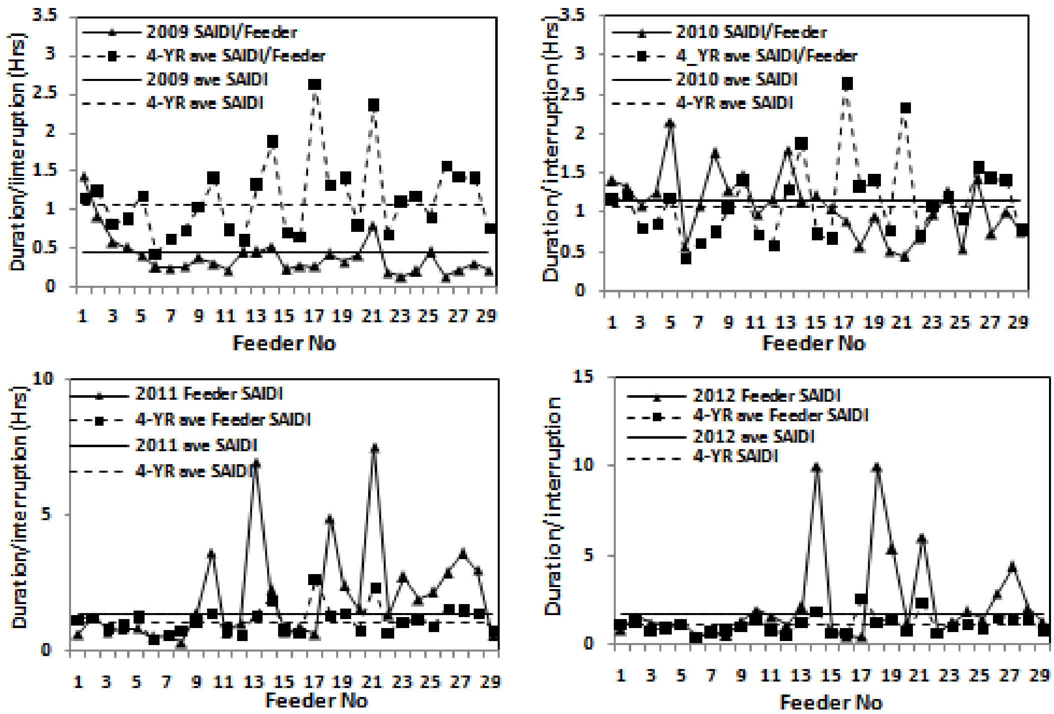


Figure 7: Various Plots of Computed ADC Feeder SAIFI and SAIDI for Years 2009 to 2012

Table 1: Computed Reliability Metrics for 33kV Feeders Supplying Various ADC Service Areas Using Field Data of 2009 to 2012

Business Unit Served	Name of Feeder	Reliability Indices				
		CAIDI* (hr/int)	SAIFI* (Int/yr)	SAIDI* (h/yr)	ASAI (%)	**ENS (MWh/yr)**
APO/KARU	H1	19.175	13.379	256.54	99.78	9213.076
APO	H2	1.100	15.862	17.45	99.98	275.856
GARKI 1	H3	9.634	16.931	163.11	99.89	4024.208
GARKI 2	H5	5.708	11.172	63.77	99.93	1008.2
GARKI 3	H7	0.968	2.379	2.30	99.98	35.92
GARKI 4	H11	0.772	3.035	2.34	99.99	75.28
APO/GARKI	H13	4.075	17.174	69.98	99.95	4684.56
GARKI 5	H15	2.629	10.000	26.29	99.96	618.44
APO/GWAGWALADA	H21	4.559	12.379	56.44	99.94	669.188
APO	H23	0.604	2.00	1.21	99.99	22.985
GWARIMPA 1	GWARINPA	4.038	18.869	76.19	99.95	1836.061
GWARIMPA/WUSE	JABI	9.326	20.689	192.95	99.89	9840.226
GWARINPA 2	LIFE CAMP	4.631	10.345	49.91	99.95	236.185
APO/GWAGWALADA	LUGBE	16.289	31.034	505.5	99.81	8636.687
WUSE 1	MAITAMA	1.807	8.172	14.77	99.97	700.39
WUSE 2	WUSE II	2.107	7.766	16.36	99.97	492.362
WUSE 3	FEEDER 1	1.116	4.345	4.84	99.98	147.35
WUSE 4	FEEDER 2	0.248	0.586	0.145	99.99	5.744
WUSE 5	FEEDER 4	0.492	1.517	0.746	99.99	6.376
WUSE 6	FEEDER 5	1.081	2.621	2.83	99.98	7.466
WUSE 7	FEEDER 6	0.192	0.241	0.046	99.99	1.416
KUBWA 1	KUBWA	2.178	11.552	25.16	99.97	384.952
KUBWA 2	DAWAKI	1.596	12.621	20.14	99.98	36.555
KUBWA 3	BWARI	2.181	10.862	23.69	99.97	380.58
KUBWA 4	DAM	1.428	3.138	4.48	99.98	23.806
GWARIMPA 3	DEI-DEI	1.725	13.448	23.2	99.98	148.379
KARU 1	FEEDER 1	0.115	0.552	0.063	99.99	0.708
KARU 3	FEEDER 3	0.697	2.345	1.63	99.99	34.732
KARU 5	FEEDR 5	0.632	2.966	1.87	99.99	45.888
ABUJA DISCO		3.486	3.486	12.15	99.96	43593.47

Equal Distribution of Customers amongst all Feeders Assumed.

Conclusion

This research has presented fairly comprehensive reliability assessment of ADC infrastructure based reliability metrics computed from field data gathered for a study period of 2009 to July, 2012. Both narrative and quantitative reliability characterizations of ADC infrastructural outlays were employed in order to proffer sound operational philosophies aimed at insuring efficient, secure, reliable and high quality electricity delivery to consumers. The results gave fairly accurate reliability picture of the actual electricity distribution activities in Federal Capital Territory, Abuja supplied by Abuja Electricity Distribution Company. It has been established that the reliability metrics so computed for ADC 33kV feeders are extremely higher than benchmark values (at least three fold). Such distribution system cannot be expected to attract consumer satisfaction or support rapid industrial growth. We therefore reiterate the profound significance of a reliable distribution network anchored on sound planning philosophy and implementation strategy as well as adoption of modern distribution automation system.

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