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The Level of Power Outage in Afikpo Distribution Network: Its Reliability Implications

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Abstract
The level of power outage in Afikpo distribution network was considered in this paper. The information used to carry out this study was collected directly from October, 2014 to February, 2015. In the raw data (which was omitted in the paper for want of space) all the intermittent lengths of time of power outage and power supply were taken daily for the period under review. The data tables shown in this paper represent the total number of lengths of time of power outage and power supply per day, per month. Statistical tools (descriptive statistics, ANOVA and trend analysis) and engineering reliability concept were used to analyze the data and inferences were drawn from the results so gotten. It was discovered that the total length of time of power outage in Afikpo distribution network is higher than the total length of time of power supply. The forecast result shows that there is only but a very bleak hope of improvement in power supply in future in the network under review.

Keywords: Power outage, Afikpo distribution network, power supply, forecast and Reliability Implications.

Introduction

Afikpo distribution network covers Abaomege, Akpoha, Ohaozara, Amasiri, Edda, Unwana and Afikpo metropolis. The network derives its source from Abakaliki, which is the Ebonyi State district headquarters of Enugu Electricity Distribution Company (EEDC). Due to the long distance from Afikpo to Abakaliki, there is a substation at Abaomege, which boosts the power to serve Afikpo distribution network and Itigidi network of Cross River State.

Most of the poles along the Akpoha, Abaomege and Abakaliki axis are wooden poles located far inside the bush through some swampy areas and arable farm lands. As a result, water logging adversely affects some of the poles while bush burning is the bane of others. When there is heavy rain, the network stands the chance of experiencing fallen poles; and during harmattan and dry seasons, the poles are not spared either as they suffer burning. All these and other system failures at the transformation units, substations and district headquarters contribute to incessant power outages on Afikpo distribution network.

Moreover, the causes of power outage in Afikpo distribution network is not only limited to the factors mentioned above as some failures are as a result of inherited problems from the national grid. For instance, the Nigeria power sector operates well below its estimated capacity with power outage being a frequent occurrence. According to Power Holding Company of Nigeria (PCHN), the country peak electric demand in 2009 was 7,600 megawatt (MW) but the actual generation capacity was 3,600 megawatt (MW) [1]. The discrepancy between electricity demand and actual generation is mostly due to low water levels, unavailability of gas to power the turbines and the inadequate plant maintenances that pervade every public power installation all over the country. At the moment, electricity generation capacity fluctuates between 2,600MW and 3,600 MW [7]. Despite the fact that this level of power generation might be grossly inadequate for a country of the size of Nigeria, one of the major problems facing the present situation and which will affect any future development is the distribution of the final sub-circuit from 11,000/415 volt which has proved more challenging [1]. It is very challenging in that almost 35% (if not more) of the power available at the distribution level is lost due to wastage [3]. Most substations and electrical networks in Nigeria were established in the 50's and 60's [4]. These networks, with some upgrading, are still functional till today with its attendant poor performance and epileptic power delivery, which has now become the headache of public power supply companies.

Recently, the present federal government of Nigeria ventured into privatizing the then Power Holding Company of Nigeria (PHCN) with a view to solving the problem of incessant power failure. This privatization exercise resulted in 18 independent units which included the transmitting company of Nigeria (TCN), 6 generating companies and 11 distribution companies [3]. Whether the process has been concluded or not; is not clear to the general public. However, one thing is obvious despite this privatization move, the constant power outage still remains a problem to the Nigeria economy.

The consequences of power outage are that there is always black out throughout the whole country; the results being factory closure, health problem, loss of life and properties and eruption of violence [4]. It also dampens economic development. Power outage in Nigeria has relationship with the generator merchants who want to sell their products and as such conspire with the leaders who as such refuse to take the right step at the right time [2]. This excessive use of generator has been blamed to be one of the major causes of environmental pollution due to emitted smoke from exhaust pipes of the generators. Erratic power supply is one major reason Nigeria is slow in industrial growth.

Objectives of the Study

The objectives of the study are:

- To determine the average length of time power is supplied to consumers in Afikpo distribution network, vis-a-vis the length of time there is power outage per day, per week and per month.
- To check if there is a significant difference in the mean-time power is **ON** and the mean time power is **OFF** in Afikpo distribution network.
- To fit the trend and forecast for 100 days the number of minutes light will be ON in Afikpo.
- To use reliability tools to determine the level of power outage in Afikpo distribution network.

Methodology

During the period under review, data were collected directly as power was supplied and taken. Each time there was power supply, the time was noted and each time there was power outage, the time was also noted. At the end of the period, the total number of hours and minutes power was supplied; and the total number of hours and minutes power was off were computed and arranged per day for each of the months. The raw data are not shown in this work but the data that show the total lengths of time for power supply and power outage are shown in tables 2, 3, 4, 5 and 6.

Hypotheses were formed and SPSS was used to run the ANOVA. Other statistical software such as Minitab and Excel were used to further analyze the data as can be on the charts that follow.

Table 1 One way ANOVA Table for a completely randomized Design

Source of Variation	Sum of Square	Degrees of freedom	Mean Square	F cal
Treatment	SSTR	$K-1$	$MSTR = \frac{SSTR}{K-1}$	$\frac{MSTR}{MSE}$
Error	SSE	$n_T - K$	$MSE = \frac{SSE}{n_T - 1}$	
Total	SST	$n_T - 1$		

$$SST = SSTR + SSE$$

$$MSTR = \frac{\sum_{j=1}^{K} n_j(\bar{x}_j - \bar{\bar{x}})^2}{K-1}$$

$$MSE = \frac{\sum_{j=1}^{K}(n_j-1)s_j^{\,2}}{n_T-K}$$

$$SSTR = \sum_{j=1}^{K} nj\left(\bar{x}_j - \bar{\bar{x}}\right)^2$$

$$SSE = \sum_{j=1}^{K}(n_j-1)s_j^{\,2}$$

Results

The following tables in the result section are results gotten from the findings made in the course of the research. These tables were then analyzed using some statistical tools and Electrical/Electronic reliability theorems.

Table 2 Power supply and power outage intervals for October, 2014

			October, 2014			
Days	HOURS ON	MINUTES ON	TOTAL MINUTES ON	HOURS OFF	MINUTES OFF	TOTAL MINUTES OFF
1	4	20	260	19	40	1180
2	0	0	0	24	0	1440
3	3	2	182	20	58	1258
4	12	50	770	11	10	670
5	0	0	0	24	0	1440
6	18	10	1090	5	50	350
7	17	31	1051	6	29	389
8	16	35	995	7	25	445
9	11	11	671	12	49	769
10	8	42	522	15	18	918
11	9	7	547	14	53	893
12	15	48	948	8	12	492
13	12	52	772	11	8	668
14	5	3	303	18	57	1137
15	8	27	507	15	33	933
16	5	23	323	18	37	1117
17	0	45	45	23	15	1395
18	15	58	958	8	2	482
19	11	36	696	12	24	744
20	12	8	728	11	52	712
21	1	22	82	22	38	1358
22	0	0	0	24	0	1440
23	0	0	0	24	0	1440
24	17	48	1068	6	12	372
25	15	29	929	8	31	511
26	6	21	381	17	39	1059
27	12	4	724	11	56	716
28	0	0	0	24	0	1440
29	0	0	0	24	0	1440

30	0	0	0	24	0	1440
31	0	0	0	24	0	1440

Table 3 Power supply and power outage intervals for November, 2014

			November, 2014			
Days	HOURS ON	MINUTES ON	TOTAL MINUTES ON	HOURS OFF	MINUTES OFF	TOTAL MINUTES OFF
1	0	0	0	24	0	1440
2	0	0	0	24	0	1440
3	0	0	0	24	0	1440
4	0	0	0	24	0	1440
5	0	0	0	24	0	1440
6	0	0	0	24	0	1440
7	0	0	0	24	0	1440
8	0	0	0	24	0	1440
9	0	0	0	24	0	1440
10	0	0	0	24	0	1440
11	0	0	0	24	0	1440
12	0	0	0	24	0	1440
13	0	0	0	24	0	1440
14	0	0	0	24	0	1440
15	0	0	0	24	0	1440
16	0	0	0	24	0	1440
17	0	0	0	24	0	1440
18	0	0	0	24	0	1440
19	0	0	0	24	0	1440
20	0	0	0	24	0	1440
21	0	0	0	24	0	1440
22	0	0	0	24	0	1440
23	0	0	0	24	0	1440
24	0	0	0	24	0	1440
25	0	0	0	24	0	1440
26	0	0	0	24	0	1440
27	0	0	0	24	0	1440
28	0	0	0	24	0	1440
29	0	0	0	24	0	1440
30	0	0	0	24	0	1440

Table 4 Power supply and power outage intervals for December, 2014

			December, 2014			
Days	HOURS ON	MINUTES ON	TOTAL MINUTES ON	HOURS OFF	MINUTES OFF	TOTAL MINUTES OFF
1	0	0	0	24	0	1440
2	0	0	0	24	0	1440
3	0	0	0	24	0	1440

4	0	0	0	24	0	1440
5	0	0	0	24	0	1440
6	0	0	0	24	0	1440
7	0	0	0	24	0	1440
8	0	0	0	24	0	1440
9	0	0	0	24	0	1440
10	0	0	0	24	0	1440
11	0	0	0	24	0	1440
12	0	0	0	24	0	1440
13	0	0	0	24	0	1440
14	0	0	0	24	0	1440
15	0	0	0	24	0	1440
16	0	0	0	24	0	1440
17	0	0	0	24	0	1440
18	0	0	0	24	0	1440
19	0	0	0	24	0	1440
20	0	0	0	24	0	1440
21	11	55	715	12	5	725
22	17	50	1070	6	10	370
23	0	0	0	24	0	1440
24	1	0	60	23	0	1380
25	11	29	689	12	31	751
26	7	6	426	16	54	1014
27	5	58	358	18	2	1082
28	24	0	1440	0	0	0
29	22	18	1338	1	42	102
30	14	24	864	9	36	576
31	14	10	850	9	50	590

Table 5 Power supply and power outage intervals for January, 2015

			January, 2015			
DAYS	HOURS ON	MINUTES ON	TOTAL MINUTES ON	HOURS OFF	MINUTES OFF	TOTAL MINUTES OFF
1	18	21	1101	5	39	339
2	7	26	446	16	34	994
3	12	24	744	11	36	696
4	5	3	303	18	57	1137
5	5	16	316	18	44	1124
6	0	0	0	24	0	1440
7	0	0	0	24	0	1440
8	0	0	0	24	0	1440
9	0	0	0	24	0	1440
10	5	50	350	18	10	1090
11	2	2	122	21	58	1318
12	5	10	310	18	50	1130
13	1	59	119	22	1	1321

14	14	35	875	9	25	565
15	14	46	886	9	14	554
16	5	12	312	18	48	1128
17	0	0	0	24	0	1440
18	0	0	0	24	0	1440
19	0	0	0	24	0	1440
20	0	0	0	24	0	1440
21	0	0	0	24	0	1440
22	0	0	0	24	0	1440
23	0	0	0	24	0	1440
24	0	0	0	24	0	1440
25	0	0	0	24	0	1440
26	0	0	0	24	0	1440
27	0	0	0	24	0	1440
28	0	0	0	24	0	1440
29	0	0	0	24	0	1440
30	0	0	0	24	0	1440
31	0	0	0	24	0	1440

Table 6 Power supply and power outage intervals for February, 2015

			February, 2015			
Days	HOURS ON	MINUTES ON	TOTAL MINUTES ON	HOURS OFF	MINUTES OFF	TOTAL MINUTES OFF
1	0	0	0	24	0	1440
2	0	0	0	24	0	1440
3	6	6	366	17	54	1074
4	8	15	495	15	45	945
5	5	43	343	18	17	1097
6	11	6	666	12	54	774
7	9	4	544	14	56	896
8	3	20	200	20	40	1240
9	5	11	311	18	49	1129
10	5	0	300	19	0	1140
11	4	30	270	19	30	1170
12	9	25	565	14	35	875
13	4	47	287	19	13	1153
14	10	23	623	13	37	817
15	5	17	317	18	43	1123
16	5	23	323	18	37	1117

Data Analysis and Interpretation

Statement of Hypothesis

H_0: There is no significant difference in the mean-time light is on and mean time light is off in Afikpo metropolis.

H_1: There is significant difference in the mean-time light is on and mean time light is off in Afikpo Metropolis.

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

Level of Significance: $\alpha = 0.05$

Test Statistic: ANOVA was used for the analysis, where SPSS statistical software was adopted.

Rejection Rule: Reject H_o if $F_{cal} > F_{Tab}$, otherwise Accept.....manual Method

SPSS Rejection Rule: Reject H_0 if Sig-value < α-value.

Table 7 SPSS Output **Descriptives**

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Mini	Maxi
					Lower Bound	Upper Bound		
LIGHT ON	139	243.5683	357.86163	30.35343	183.5504	303.5863	.00	1440.00
LIGHT OFF	139	1196.4317	357.86163	30.35343	1136.4137	1256.4496	.00	1440.00
Total	278	720.0000	596.16205	35.75542	649.6131	790.3869	.00	1440.00

Table 8 ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	63102419.799	1	63102419.799	492.738	.000
Within Groups	35345924.201	276	128064.943		
Total	98448344.000	277			

From table 7, the average number of minutes light was **ON** in Afikpo per day is 243mins 57sec, while the average number of minutes light was **OFF** in Afikpo per day is 1196mins 43sec.

Similarly, table 8 shows that Sig. value is less than α value. That is Sig. value = 0.000 < α-value = 0.05 which implies that there is sufficient evidence to reject H_0 and accept H_1.

Judging from the above premises it can be inferred that there is a significant difference between the mean time light was **ON** and mean time light was **OFF** in Afikpo Metropolis.

Trend Analysis

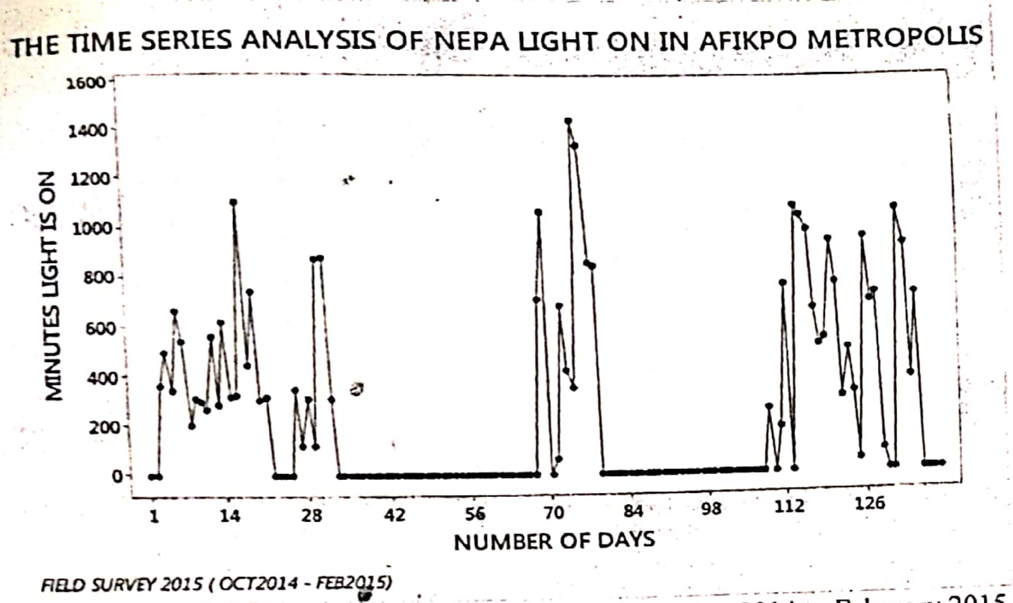

Figure 1 The trend of power supply in Afikpo from October 2014 to February 2015

The time series plot in figure 1 above shows that light in Afikpo Metropolis has no definite pattern.
Data: Minutes light was ON
Length: 139
N Missing: 0
Fitted Trend Equation: $Yt = 187.5 + 0.801t$

Forecast for Light Distribution in Minutes Per day in Afikpo Metropolis for 100 days

Table 9 Forecast for 100 days

Days	Forecast	Days	Forecast	Days	Forecast	Days	Forecast
1	299.657	26	319.689	51	339.721	76	359.752
2	300.458	27	320.49	52	340.522	77	360.554
3	301.26	28	321.291	53	341.323	78	361.355
4	302.061	29	322.093	54	342.124	79	362.156
5	302.862	30	322.894	55	342.926	80	362.957
6	303.664	31	323.695	56	343.727	81	363.759
7	304.465	32	324.497	57	344.528	82	364.56
8	305.266	33	325.298	58	345.33	83	365.361
9	306.067	34	326.099	59	346.131	84	366.163
10	306.869	35	326.9	60	346.932	85	366.964
11	307.67	36	327.702	61	347.733	86	367.765
12	308.471	37	328.503	62	348.535	87	368.566
13	309.272	38	329.304	63	349.336	88	369.368
14	310.074	39	330.105	64	350.137	89	370.169

15	310.875	40	330.907	65	350.938	90	370.97
16	311.676	41	331.708	66	351.74	91	371.771
17	312.477	42	332.509	67	352.541	92	372.573
18	313.279	43	333.31	68	353.342	93	373.374
19	314.08	44	334.112	69	354.143	94	374.175
20	314.881	45	334.913	70	354.945	95	374.976
21	315.683	46	335.714	71	355.746	96	375.778
22	316.484	47	336.516	72	356.547	97	376.579
23	317.285	48	337.317	73	357.349	98	377.38
24	318.086	49	338.118	74	358.15	99	378.182
25	318.888	50	338.919	75	358.951	100	378.983

Reliability Implications Result

The reliability implications of this distribution network were determined by the calculations carried out below and the result deposited in table 10. The calculation is for the month of October 2014, but those of other months were not shown for want of space.

$$Total\ number\ of\ hours, t_n = 501 \cdot 5\ hours$$
$$Time\ of\ start\ of\ study, t_0 = 19 \cdot 7\ hours$$
$$Number\ of\ failures, n = 31\ times\ in\ the\ month$$

$$Mean\ Time\ Between\ Failures, MTBF(M) = \frac{T}{n} = \frac{(t_1 - t_0) + (t_2 - t_1) + \cdots + (t_n - t_{n-1})}{n} = \frac{(t_n - t_0)}{n}$$
$$= \frac{t_n}{n}$$

$$M = \frac{(t_n - t_0)}{n} = \frac{501.5 - 19.7}{31} = \frac{481.8}{31} = 15.54\ hours$$

$$Failure\ Rate\ (\lambda) = \frac{1}{MTBF} = \frac{1}{M} = \frac{1}{15.54} = 0.0644\ per\ hour$$
$$Total\ time\ of\ study\ for\ the\ month\ (t) = 31 days \times 24\ hours\ in\ a\ day = 744\ hours$$
$$The\ reliability\ result\ for\ the\ month\ (R) = e^{-\lambda t} = e^{-(0.0644 \times 744)} = e^{-47.914} = 1.55 \times 10^{-21}$$
$$Reliability\ (R)\ plus\ power\ failure\ (Q) equals\ one$$
$$Mathematically, R + Q = 1; such\ that\ Q = 1 - R = 1 - 1.55 \times 10^{-21} \approx 1$$

Table 10: The reliability implications of the power outage

Days	October, 2014	November, 2014	December, 2014	January, 2015	February, 2015
1	1180	1440	1440	339	1440
2	1440	1440	1440	994	1440
3	1258	1440	1440	696	1074
4	670	1440	1440	1137	945
5	1440	1440	1440	1124	1097
6	350	1440	1440	1440	774
7	389	1440	1440	1440	896

8	445	1440	1440	1440	1240
9	769	1440	1440	1440	1129
10	918	1440	1440	1090	1140
11	893	1440	1440	1318	1170
12	492	1440	1440	1130	875
13	668	1440	1440	1321	1153
14	1137	1440	1440	565	817
15	933	1440	1440	554	1123
16	1117	1440	1440	1128	1117
17	1395	1440	1440	1440	0
18	482	1440	1440	1440	0
19	744	1440	1440	1440	0
20	712	1440	1440	1440	0
21	1358	1440	725	1440	0
22	1440	1440	370	1440	0
23	1440	1440	1440	1440	0
24	372	1440	1380	1440	0
25	511	1440	751	1440	0
26	1059	1440	1014	1440	0
27	716	1440	1082	1440	0
28	1440	1440	0	1440	0
29	1440	1440	102	1440	0
30	1440	1440	576	1440	0
31	1440	0	590	1440	0
Total Minutes of Power Outage	30088	43200	36830	38756	17430
Total Hours of Power Outage	501.47	720	613.83	645.93	290.5

Table 11: Reliability considerations

Reliability Factors							
Months	Time to the nth Failure(t_n)	Time of start of Failure(t_0)	Number of Failures (n)	Mean time to Failure(MTBF)(M)	Failure rate(λ)	Reliability (R)	Failure (Q)
October	501.47	19.7	31	15.54	0.0644	1.55E-21	≈1
November	720	24	30	23.2	0.0431	3.33E-14	≈1
December	613.83	24	30	19.66	0.0509	1.21E-16	≈1
January	645.93	5.65	31	20.65	0.0484	2.29E-16	≈1
Febuary	290.5	24	16	16.66	0.06	9.86E-11	≈1

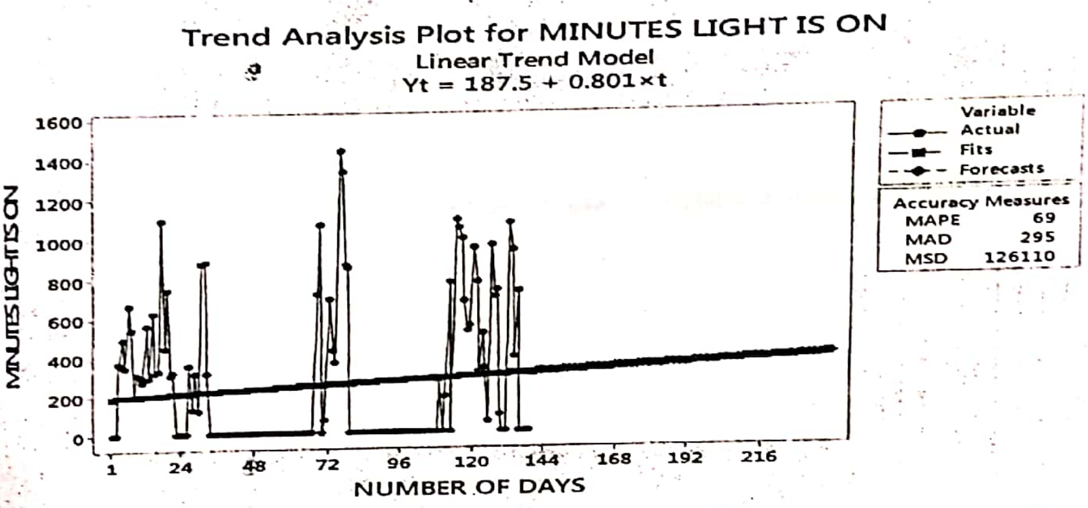

Figure 2 Trend analysis and forecast

The trend plot in figure 2 and the forecast table, table 3 reveal that there is a very sluggish upward movement of light ON in Afikpo Metropolis. The increase is not significant.

Line Graph Analysis

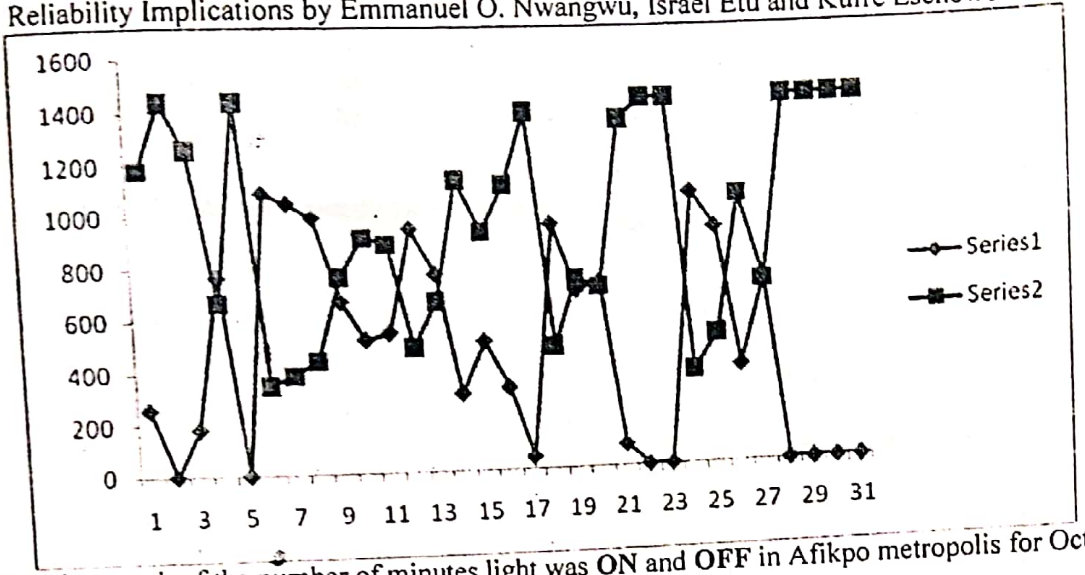

Figure 3 Line graph of the number of minutes light was **ON** and **OFF** in Afikpo metropolis for October 2014

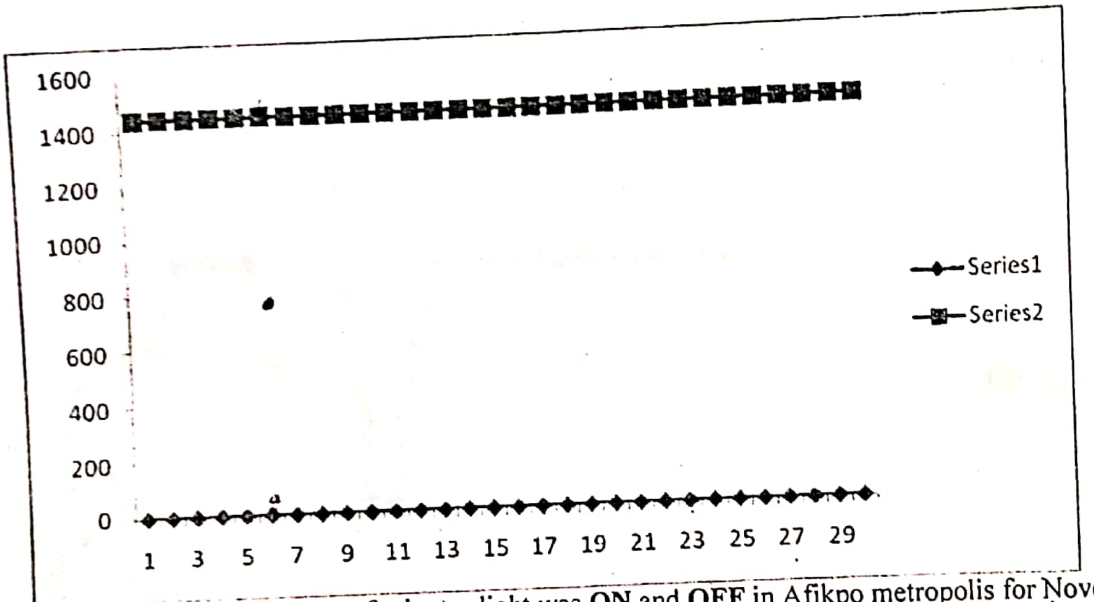

Figure 4 Line graph of the number of minutes light was **ON** and **OFF** in Afikpo metropolis for November 2014

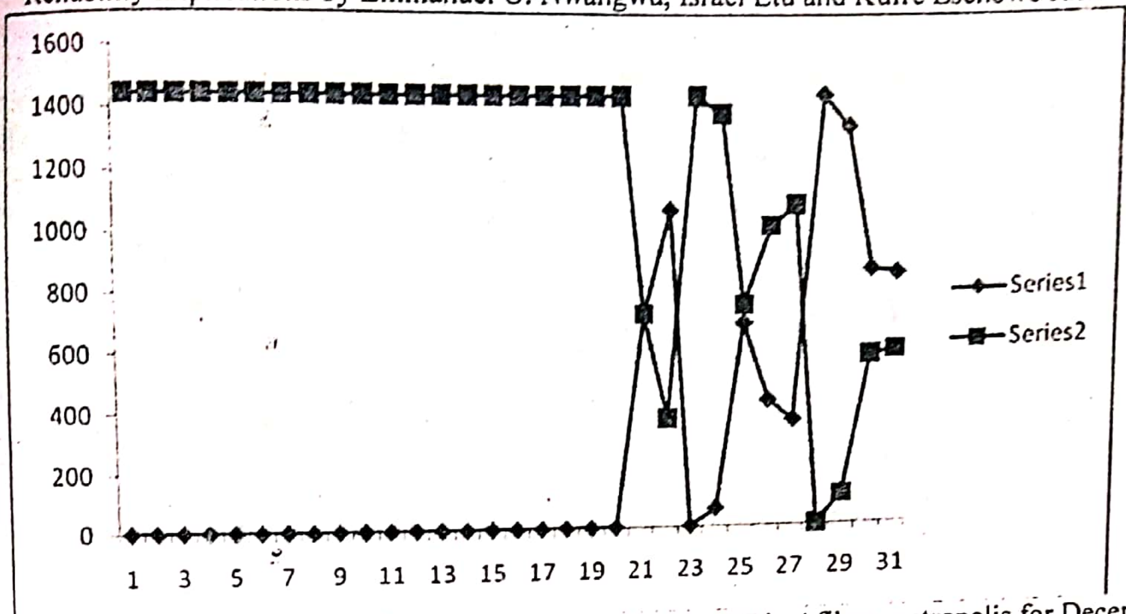

Figure 5 Line graph of the number of minutes light was **ON** and **OFF** in Afikpo metropolis for December 2014

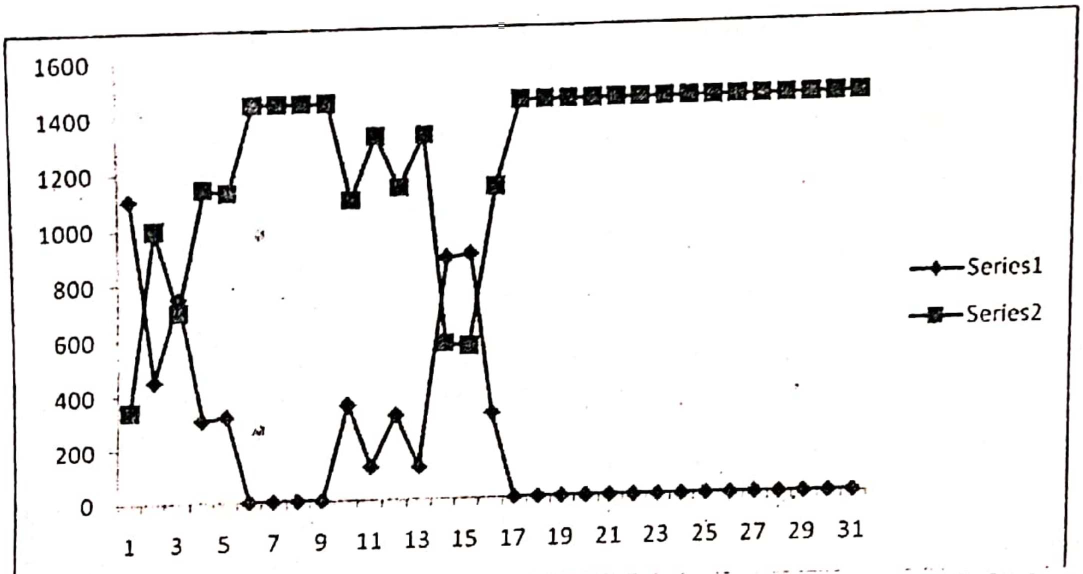

Figure 6 Line graph of the number of minutes light was **ON** and **OFF** in Afikpo metropolis for January 2015

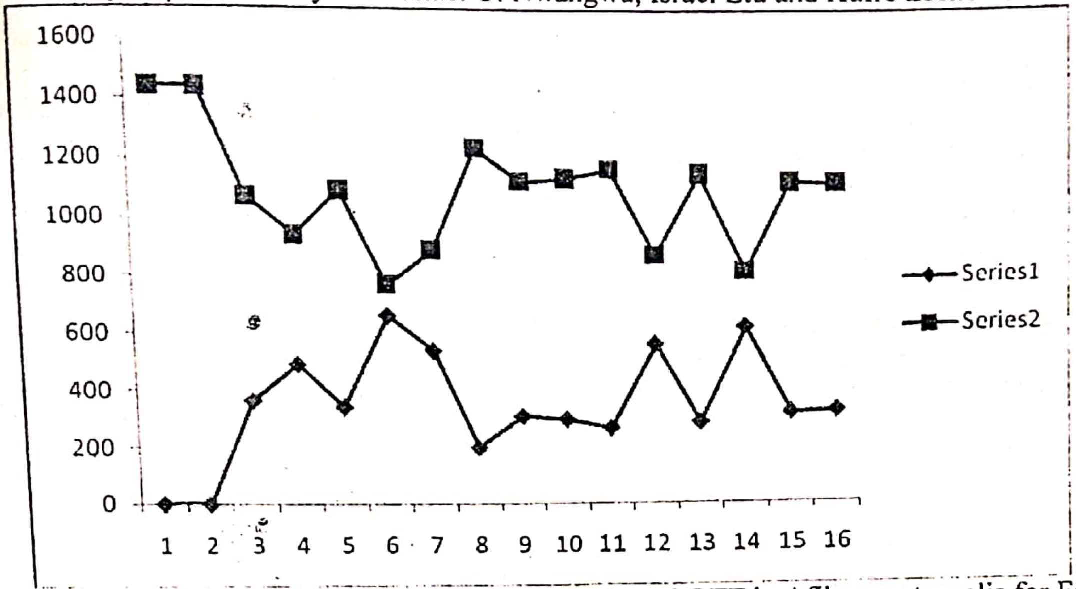

Figure 7 Line graph of the number of minutes light was **ON** and **OFF** in Afikpo metropolis for February 2015

Series 1 = Light ON
Series 2 = Light OFF

Discussion

From the foregoing, it has been discovered that Afikpo Distribution Network has a very bad case of incessant power failure. The average length of time power is supplied in Afikpo per day is paltry 243 minutes, 56 seconds while the average length of time power is OFF per day is a whole lot of 1196 minutes, 43 seconds. This translates to a power ON period of about 4 hours a day and a power OFF period of about 20 hours a day. In a week, it is power ON period of about 28 hours (an aggregate of 1 day and 4 hours) and power OFF period of about 140 hours (an aggregate of 5 days and 20 hours). In a month, it is power ON period of about 4 days, 16 hours and power OFF period of 23 days and 8 hours.

Forecast of 100 days into the future has nothing good to offer either. It shows a very sluggish improvement in power supply from 299 minutes, 66 seconds a day to only 378 minutes, 98 seconds; an insignificant difference of 79 minutes, 32 seconds.

The reliability considerations as presented in tables 10 and 11 reveal that the power outage in Afikpo distribution network has serious adverse effect on the dwellers to the extent that the reliability is almost zero, thereby giving a failure value of almost one. In a normal situation, the reliability of a system is supposed to be one or approaching one, thereby giving a failure value that approaches zero. The implication of the situation of this distribution network is that nobody should rely on the public power supply of the network since the reliability is grossly low.

This scenario only presents a very bleak future for power consumers in this network. Therefore, whosoever needs light for his daily activities should better look for an alternative source of power supply as public power supply source is practically hopeless.

Conclusion and Recommendation

That power supply in Afikpo is grossly inadequate is no longer debatable at this juncture. This is evidenced by the reliability investigation as contained in this study, where the reliability of the system which is supposed to be one, is rather approaching zero. This puts the failure, which is the opposite of reliability at close to one, instead of zero. All the calculations, charts and trends have simply consolidated the argument. The forecast is as a result of the trend of power supply for the period under review. It simply followed this trend and lent its support to the subject matter. What is now left is for power consumers in the network to take individual precautions to contain this menace. This is because if the trend of power supply in this continues the way it is going, the consumers do not have any tangible hope of enjoying power from public supply in the near future.

By way of recommendation, government is urged to stop paying lip service to the project of improving power supply in this country. This is a function of corruption in high places of government. It has always been the act of successive governments for many years now and the result is a steady decline in the adequacy of power supply in the country.

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