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A Statistical Study of the Electric Load Distribution in some areas of the Benin Municipality, Edo state, Nigeria

Olugbenga E. Olofin[1], Iyabo S. Oghenevwaire [2], Oluwayomi J. Oyejide[2*]
[1]*Department of Production Engineering, University of Benin, Benin City, Nigeria.*
[2] *Department of Mechanical Engineering, Federal University of Petroleum Resources, P.M.B 1221, Effurun, Delta State, Nigeria*
Corresponding author: [*] *(oyejide.joel@fupre.edu.ng)*

Abstract
The electric utility industry is probably the largest and the most complex in the world. Absence of electricity for long periods causes discomfort and hampers productivity. It is also a known fact that electricity consumption has become a parameter by which the standard of living as well as the level of industrialization of nations is measured. This research work is therefore carried out to determine the correlation of the peak loads between the feeders supplying the distribution substations in order to make sound interpretation on the variations of the peak load between them. A research design was carried out base on peak load (PL) data for five (5) different feeders supplying within Benin distribution zone of the Benin Electricity Distribution Company (BEDC) of Nigeria. The data used in this research work were monthly records on electricity supply having the highest peak load dealing on transmission stations; the monthly record was obtained for the period of two years (May 2000- May 2002) on a 5 point areas. The collected data was analyzed using the correlation analysis. Pearson rule was applied to bring out the square matrix of 5 x 24 data matrix into 5 x 5 matrixes. Also one way ANOVA was integrated. Computation of sum of squares of sources of variation for these two design matrix (morning peak load and evening peak load) was carried out using Fisher-Yates algorithm. The results analysis revealed that load consumption among the substations follow similar pattern. This simply shows that load distributions as well as power outages in Benin City appear to be the same. Besides, relatively high correlation of 0.9 was obtained for industries area in Benin such as UNIBEN, UBTH, COLBEN, Psychiatric Hospital, etc., positioned in the Guinness Axis and this revealed that preference is given to industrial area of Benin metropolis.

Key words: Peak load, ANOVA, electricity distribution, research design, feeders

1. Introduction

Electric power supply is the most important commodity for national development. With electrical energy the people are empowered to work from the domestic level and the cottage industries, through the small-scale and medium industries to employment in the large-scale manufacturing complexes *(Odior, et al., 2010)*. The first electric power generating plant in Nigeria was installed in Ijora, Lagos in 1896. With the trend in electricity development, other cities follow suit. Port

Harcourt, Kaduna, Enugu, Maiduguri, Yola, Zaria, Warri and Calabar became electrified in the year 1928, 1929, 1933, 1937, 1938 and 1939 respectively. From 1930 wealthy Native Authority (NA) - like Kano, Katsina, Abeokuta and Ibadan - started the installation and operation of their own power plants respectively in the years 1930, 1933, 1935 and 1940. By 1950, ordinance No 15 established the Electricity Corporation of Nigeria (ECN). Nigeria Government Electricity Undertaking (NGEU), which has been operating, bilaterally with the NA handed over to the ECN on April 1, 1951. Lagos and Ibadan in 1959 became the first two towns in Nigeria to be linked through transmission line with injection substations. Public power supply in Nigeria is generally unsteady and the situation is extensively attributed to various causes such as political disorientation, endemic corruption, inappropriate maintenance culture and managerial deficiency. The Benin City Electricity Distribution Company of Nigeria (BEDC) formerly known as National Electric Power Authority (NEPA) is the organization responsible for the distribution of electric power in the Benin metropolis and its environs. The organization noted that the problem in the electric power sector revolves around three major causes namely: Generation, Transmission, and Distribution.

The electric utility industry is probably the largest and the most complex in the world *(Happ, 1994; Ilia et al., 1997; Park et al., 1998)*. For instance, in Nigeria, the electricity industry is in the process of deregulation and it is proposed that the old National Electric Power Authority (NEPA) now Power Holding Company of Nigeria (PHCN) which had a whole responsibility of generation, transmission and distribution of electricity, would be unbundled into six generating companies, eleven distribution companies and just one transmission company. This move is mainly to accommodate the increasing population. Due to population growth and subsequent increased demand for higher efficiency and reliable electricity supply, power systems are being forced to operate at almost full capacity *(Silva et al., 1998; Ajose et al., 2005; Berman, et al., 2002)*. Also, the complexity of a power system is directly proportional to the number of buses which it serves (*Berman, et al., 2002)*. In the past, several researchers have adopted statistical tools and model in solving problems facing mankind. For instance, Wu *(1981)* reported on asymptotic inference from sequential design in a nonlinear situation. The main objective of this study was to show that there is a major difficulty in designing a nonlinear experiment. Morris and Mitchell Morris, *(1983)* reported on two level multifactor designs for detecting the presence of interactions. The main objective of this study is an experimental programs to approximate the relationship between an observed response variable y and k controllable variable (factors) frequently use at some stage. This report shows an augmentation of the tr (L) – optimal designs that achieve a compromise between the criteria of D – optimality and tr (L) – optimality. Donvec *(2004)* reported on design of experiments in the presence of errors in factor levels. The main objective of this study is to show how various experimental designs are used routinely in many statistical investigations. For example two level factorial or fractional design is used when a response variable of interest can be explained also contain interactions of a number of factors. From this study, it was seen that there are difficulties in setting decisively the degrees of the components in an experimental design which then influences the aftereffect of the investigation. At the point when the errors cannot be measured the actual design that is used is unknown and the planned design is used in the analysis of the data This presents heterogeneity in the fluctuation of productivity in evaluating the parameters of the model.

However, this research work will proffer solutions to some of the issues and challenges in one of the distribution companies named Benin electricity Distribution Company in the Southern zone of Nigeria. One-way ANOVA was adopted. Also, the correlation matrix of the outage duration and load losses from the obtained data matrix was determine. Moreso, the Fisher-Yates' algorithm was applied.

2.Methods

2.1 Research Design

Peak load (PL) data for five (5) different feeders supplying within Benin distribution zone of the Benin Electricity Distribution Company (BEDC) were obtained. The data were monthly observation dealing with PL output resulting from planned, forced and emergency situations, as categorized during the data filtering process. The peak load output was summed up based on their associated reasons for outages for various feeders within the research area.

2.2 Data Collection

The data used in this research work were monthly records on electricity supply having the highest peak load dealing on transmission stations; the monthly record was obtained for the period of May 2000 to May 2002 on 5 point areas. The data collected represented a sample of peak load record from BEDC. The record covers all the common reasons for PL within the distribution zone and the sample covers all the events resulting to and from the reasons for Peak load stated. The concept of the management BEDC center was sought on the basis of which data was released. The data were in a log book indicating monthly reporting of peak load at various regions. The reasons for peak load (RFOs) were classified into planned forced and emergency. The distribution voltage is maintained at 33kv to accommodate losses associated with distribution lines. The PL period were recorded in a time-in time-out format. This was extracted and recorded in minute's base on monthly output. Load consumption for five feeder's centers in Benin City for morning and evening respectively namely Etete, G.R.A, Guinness, Ikpoba Dam, and nekenekpe are shown in Table 1 and Table 2

Table 1: Morning Peak Load (May 2000 – May 2002)

Morning peak load May 2000 - May 2002				
Guinness Feeder	**Nekenekpe Feeder**	**Ikpoba Dam Feeder**	**Etete Feedee**	**GRA feeder**
456	286	150	504	240
432	286	145	536	240
480	248	148	480	352
480	0	146	519	368
480	248	130	528	376
456	320	145	528	344
460	224	122	480	266

480	164	144	540	257
492	176	146	508	258
456	194	150	552	232
480	196	130	480	244
468	198	130	480	216
438	200	140	480	244
480	224	220	552	220
450	204	245	561	206
444	204	300	552	212
432	200	208	624	232
494	220	248	651	241
444	336	290	648	284
480	342	325	634	360
576	366	310	522	384
510	348	280	456	420
492	336	256	480	386
498	396	318	480	366

Table 2. Evening Peak Load (May 2000 – May 2002)

Evening Peak Load (May 2000 - May 2002)				
Guinness Feeder	Nekenekpe Feeder	Ikpoba dam Feeder	Etete Feeder	GRA feeder
456	248	135	504	260
444	286	145	536	232
480	248	148	480	352
490	0	146	520	384
480	248	130	528	376
456	320	146	480	344
456	224	122	480	266
480	164	144	540	316
480	160	148	518	246
468	220	140	558	250
480	200	145	552	280
456	218	132	552	248
468	318	145	480	240
456	220	140	504	244
456	270	212	486	240
484	240	212	540	227
450	240	268	558	232
468	234	245	582	236
480	248	250	678	248
504	366	300	700	268

588	390	310	700	372
576	372	393	576	420
600	390	360	700	420
516	360	296	528	420

2.3 Data Analysis

The collected data was analyzed using the correlation analysis. Pearson rule was applied to bring out the square matrix of 5 x 24 data matrix into 5 x 5 matrixes. Also one way ANOVA was integrated. Computation of sum of squares of sources of variation for these two design matrix (morning peak load and evening peak load) was carried out using Fisher-Yates algorithm. This allowed the computation of mean squares that are needed to take decision on the null hypothesis using analysis of variance statistical tech. The Fishers-Yates algorithm can be employed to obtain the associated sum of squares of various sources of variations needed for analysis of variance (ANOVA) null hypothesis decision making *(Igboanugo, 2010)*.

$$SST = \sum_{j=i}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - C; \quad where\ C = \frac{(X_{..})^2}{nT} \quad (1)$$

$$SSA = \sum_{i=1}^{J} \frac{(X_{ij})^2}{n_j} - C \qquad n_T = \sum_{j=1}^{J} n_j \quad (2)$$

$$SST = \sum_{j=i}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - \frac{(X_{..})^2}{nT} \quad (3)$$

$$SSE = SST - SSA = \sum_{j=1}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - \sum_{j=1}^{J} \frac{(X_{.j})^2}{n_j} \quad (4)$$

The ANOVA for Evening Peak Load (PL) is represented in Equation (5) to Equation (8).

$$SST = \sum_{j=i}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - C; \quad where\ C = \frac{(X_{..})^2}{nT} \quad (5)$$

$$SSA = \sum_{i=1}^{J} \frac{(X_{ij})^2}{n_j} - C \qquad n_T = \sum_{j=1}^{J} n_j \quad (6)$$

$$SST = \sum_{j=i}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - \frac{(X_{..})^2}{nT} \quad (7)$$

$$SSE = SST - SSA = \sum_{j=1}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - \sum_{j=1}^{J} \frac{(X_{.j})^2}{n_j} \quad (8)$$

Sum of squares of total

$$SS_T = \sum_{i=1}^{3} \sum_{j=1}^{6} \sum_{k=1}^{1} \sum_{l=1}^{1} \sum_{m=2}^{8} X_{ijklm^-}^2 \frac{X^2.....}{IJKLM} \quad (9)$$

Sum of squares for surrounding outage circumstance ($SS_{morning}$)

$$SS_{SOC} = \sum_{i=1}^{3} \frac{Xi^2...}{JKLM} - \frac{X^2...}{IJKLM} \quad (10)$$

Sum of squares for distribution centre ($SS_{evening}$)

$$SS_D = \frac{\sum X_{.j...}^2}{IKLM} - \frac{X_{......}^2}{IJKLM} \quad (11)$$

3. Results and Discussion

3.1 Presentation of Results

The data in the Table 1 and Table 2 were used to conduct one-way ANOVA. The results obtained are as follow. Table 3 shows the results analysis of ANOVA for morning peak l.oad

Table 3: ANOVA Analysis for Morning Peak Load

gf*2	nk*2	if*2	ef*2	grf*2
207936	81796	22500	254016	57600
186624	81796	21025	287296	57600
230400	61504	21904	230400	123904
230400	0	21316	269361	135424
230400	61504	16900	278784	141376
207936	102400	21025	278784	118336
211600	50176	14884	230400	70756
230400	26896	20736	291600	66049
242064	30976	21316	258064	66564
207936	37636	22500	304704	53824
230400	38416	16900	230400	59536
219024	39204	16900	230400	46656
191844	40000	19600	230400	59536
230400	50176	48400	304704	48400
202500	41616	60025	314721	42436
197136	41616	90000	304704	44944
186624	40000	43264	389376	53824
244036	48400	61504	423801	58081
197136	112896	84100	419904	80656
230400	116964	105625	401956	129600
331776	133956	96100	272484	147456
260100	121104	78400	207936	176400
242064	112896	65536	230400	148996
248004	156816	101123.7	230400	133956
5397140	**1628744**	**1091583.7**	**6874995**	**2121910**
				17114372.7

Morning peak load (May 2000- May 2002)

$$SST = \sum_{j=1}^{J} \sum_{i=1}^{n_j} X_{i.j}^2 - C$$

$$C = \frac{(X..)^2}{n_T} = \frac{1749163329}{120} = 14576361108$$

$$n_T = \sum_{J=1}^{5} n_j = 120$$

$$\therefore SST = 17114373 - 1457636108$$

SST = 253801192

$$SSA = \sum_{j=1}^{J} \frac{(X_{.j})^2}{n_j} - C$$

$$\therefore SSA = 375608851 - 1457636108$$

$$SSA = 3610324899$$
$$SSE = SST - SSA$$
$$= \sum_{j=1}^{J} \sum_{i=1}^{n_j} X_{ij}^2 - \sum^{J} j = 1 \frac{(x_j)^2}{n_i}$$
$$\therefore SSE = 253801192 - 3610324899$$
$$SSE = -35849478$$

Table 4 shows the symbolic presentation of the analysis of the variance

Table 4. Symbolic Presentation of the Analysis of Variance

Source of variability	**Df**	**SS**	**MS**	**F ratio**
Among treatment j – 1	$df_A = j-1$ $=5-1=4$	$SSA = 3610324899$	$MSA = \frac{SSA}{dfA} = \frac{3610324899}{4}$ $= 90,258,122.48$	$F = \frac{MAS}{MSE} =$ $\frac{90258,122.48}{-311,734.59} = -289.535$
Error	$dft = n_T - j$ $=120-5$ $=115$	$SSE =$ -3584978	$MSE = \frac{SSE}{dfE}$ $= \frac{-35849478}{115}$ $= -311,734.59$	
Total	$df_T = n_T - 1$ $120-1-119$	$SST =$ 253801192		

Table 5 shows results of ANOVA Analysis for evening peak load

Table 5. ANOVA Analysis for Evening Peak Load

gf*2	nf*2	if*2	ef*2	grf*2
207936	61504	18225	254016	67600
197136	81796	21025	287296	53824
230400	61504	21904	230400	123904
240100	0	21316	270400	147456
230400	61504	16900	278784	141376
207936	102400	21316	230400	118336
207936	50176	14884	230400	70756
230400	26896	20736	291600	99856
230400	25600	21904	268324	60516
219024	48400	19600	311364	62500
230400	40000	21025	304704	78400
207936	47524	17424	304704	61504
219024	101124	21025	230400	57600
207936	48400	19600	254016	59536

207936	72900	44944	236196	57600
234256	57600	44944	291600	51529
202500	57600	71824	311364	53824
219024	54756	60025	338724	55696
230400	61504	62500	459684	61504
254016	133956	90000	490000	71824
345744	152100	96100	490000	138384
331776	138384	154449	331776	176400
360000	152100	129600	490000	176400
266256	129600	87616	278784	176400
5718872	**1767328**	**1118886**	**7464936**	**2222725**
				18292747

Evening peak load (May 200- May 2002)

SST $\sum_{J=1}^{J} \sum_{i=1}^{n_j} X_{i.j}^2 - C$

$C = \frac{(X..)^2}{nT} = \frac{1854938761}{120} = 15{,}45982301$

SST = $18292747 - 1545782301$

SST= 283492399

SSA = $\sum_{j=1}^{J} \frac{(X.j)^2}{n_j} - C$

SSA= $424699825 - 15{,}45782301$

SSE = $SST - SSA$

SSE = $283492399 - 409242002$

SSE = $406{,}407{,}078$

Table 6 shows symbolic presentation of the analysis of variance

Table 6. Symbolic Presentation of the Analysis of Variance

Source of variability	Df	SS	MS	F ration
Among treatment j – 1 = 4	$df_A = j - 1$ $= 5 - = 4$	$SSA = 409242002$	$MSA = \frac{SSA}{dfA} = \frac{409242002}{4}$ $= 102{,}310{,}500.5$	$F = \frac{MAS}{MSE} =$ $\frac{102{,}310.500.5}{-28.95055}$
Error	$dft = n_T - \supset$ $= 120 - 5$ $= 115$	$SSE =$ $-406{,}407{,}078$	$MSE = \frac{SSE}{dfE}$ $= \frac{-406{,}407{,}078}{115}$ $= -3{,}533{,}974.59$	

Total	$df_r = nT - 1$ $120-1-119$	$SST =$ 283492399		

Correlation Analysis

The data of Table 1 and Table 2 were used to compute correlation matrices as shown in the accompanying Table 7 and Table 8 respectively

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & - & - & - & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} & - & - & - & a_{224} \\ a_{31} & a_{32} & a_{33} & a_{34} & - & - & - & a_{324} \\ a_{41} & a_{42} & a_{43} & a_{44} & - & - & - & a_{424} \\ a_{51} & a_{52} & a_{53} & a_{54} & - & - & - & a_{524} \end{bmatrix}$$

$$X_{ij} = \begin{bmatrix} a_{ij} \\ a_{2j} \\ i \\ a_{5j} \end{bmatrix} \begin{matrix} i = 1, 2, - - - -5; \\ j = 1, 2, - - - -, 24 \end{matrix}$$

Also $y_{ik} = \begin{bmatrix} a_{ik} \\ a_{2k} \\ a_{5k} \end{bmatrix}$ j where j and k represent two different-columns

The $x = x_{ij} - \bar{x}_{.j}; \bar{x}_{.j} = \frac{\sum_{1=i}^{5} x_{ij}}{n_j}$

From the correlation analysis relation or Pearson Formulae

$$COS\theta = r_{ij} = r_{ji} = \frac{\sum xy}{\sqrt{\sum x^2 x \sum y^2}} = \frac{\sum (x_1 - \bar{x})(y - \bar{y})}{\sqrt{\sum (x, -\bar{x})^2 \times \sum (y - \bar{y})^2}}$$

$$nC_r = nC_2$$

$$= \frac{5.4.3.2.1}{5.3.2.1 \times 2.1} = 10$$

Table 7. Sample table for Evening Correlation Computation

S/N	***X***	***Y***	$x\,(x-\bar{x})$	$y\,(y-\bar{y})$	xy	x^2	y^2
1	456	-5.8	-5.8	-14	-81.2	33.64	196
2	444	4.2	4.2	-26	-109.2	17.64	676
3	480	7.2	7.2	10	72	51.84	100
4	490	5.8	5.8	20	116	33.64	400
5	480	-10.8	-10.8	10	108	116.64	100
					105.6	253.4	1472

$$\bar{x} = \frac{135+145+148+146+130}{5} = 140.8$$

$$\bar{y} = \frac{456+444+480+490+480}{5} = 470$$

$$r_{31} = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}} \quad \frac{105.6}{\sqrt{253.4 \times 1472}} = \frac{105.6}{610.741}$$

$$r_{31} = 0.1729$$

Also,

Table 8. Sample Table for Evening Correlation Computation

	X	Y	$x(x-\bar{x})$	$y(y-\bar{y})$	xy	x^2	y^2
1	456	248	-14	42	-588	196	1764
2	444	286	-26	80	-2080	676	6400
3	480	248	10	42	420	100	1764
4	490	0	20	-206	-4120	400	42436
5	480	248	10	42	420	100	1764
					-5,948	1472	54.128

$$\bar{x} = \frac{456+444+480+490+480}{5} = 2350/5 = 470$$

$$\bar{y} = \frac{248+286+248+0+248}{5} = 1030/5 = 206$$

$$r_{21} = \frac{\sum xy}{\sqrt{\sum x^2 \ \sum y^2}} = \frac{-5948}{\sqrt{1472 \times 54.128}} = \frac{-5948}{8926.16} = -0.666$$

Table 9. Correlation Table for Morning Peak Load

C/ r	1	2	3	4	5
1	1				
2	-0.502	1			
3	-0.3024	-0.688	1		
4	-0.451	-0.083	0.512	1	
5	0.911	-0.562	-0.511	-0.1695	1

Table 10. Correlation table for Evening peak load

C/ r	1	2	3	4	5
1	1				
2	0.666	1			
3	0.066	-0.3092	1		
4	-0.3006	-0..0713	0.3074	1	
5	0.985	-0.585	-0.0287	.0202	1

The correlation matrices of Table 9 and Table 10 were feed into MATLAB software using the accompanying MATLAB command and eigenvalues were obtained as shown.

Matrix Result

```
>> A=[1 -0.502 -0.3024 -0.451 0.911;-0.502 1 -0.688 -0.083 -0.562;-0.3024 -0.688 1 0.512 -0.511;-0.451 -0.083 0.512 1 -0.1695;0.911 -0.562 -0.511 -0.1695 1]
A =
     1.0000   -0.5020   -0.3024   -0.4510    0.9110
    -0.5020    1.0000   -0.6880   -0.0830   -0.5620
    -0.3024   -0.6880    1.0000    0.5120   -0.5110
    -0.4510   -0.0830    0.5120    1.0000   -0.1695
     0.9110   -0.5620   -0.5110   -0.1695    1.0000
```

Eigen Value Result

```
>> e=eig(A)
   e =
    -0.2084
     0.0951
     0.7158
     1.8703
     2.5272

>> [v,d]=eig(A)
     v =
    -0.1247   -0.7780   -0.0452    0.1164    0.6030
     0.5342   -0.3970    0.1881   -0.6748   -0.2574
     0.5885   -0.2263   -0.3293    0.6278   -0.3162
    -0.1798   -0.2275    0.8249    0.3498   -0.3364
     0.5661    0.3663    0.4168    0.1209    0.5975

   d =
    -0.2084         0         0         0         0
          0    0.0951         0         0         0
          0         0    0.7158         0         0
          0         0         0    1.8703         0
          0         0         0         0    2.5272
```

3.2 Discussion

As shown in Table 3, since $F_{cal} = -289.53 < F_{tab} = 2.45$, our expected data do not provide sufficient evidence form to reject the null hypothesis H_0. Thus, there is no differential treatment. In other words load consumption among the substations studied follow similar pattern. Also, since $F_{cal} = -28.95 < F_{tab} = 2.45$, our expected data do not provide sufficient evidence form to reject the null hypothesis H_0. Hence, there is no differential treatment. In other words, load consumption among the substations studied follow similar pattern. The implication is that load distributions as well as power outages in Benin City appear to be the same. Besides, the coefficient as noticed shows that it is very salient from the correlation that Guinness Feeder and G.R.A Feeder share similar load pattern. This phenomenon may not be unconnected that important people lives in G.R.A and so attract preferential treatments. In the same way, industries such as UNIBEN, UBTH, COLBEN, Psychiatric Hospital, and some other important institutions positioned in the Guinness Axis attract important treatment also and hence, the high correlation of 0.9. The other correlations are similarly interpreted.

Furthermore, the eigenvalues show the priority rating of the stations by ordering them in merit order sequential ties. Thus, the higher the eigenvalue, the more important the feeder station in terms of load consumption.

Conclusion

It is evident from the foregoing analyses that the Guinness Feeder axis which supplies the important institutions mentioned earlier receives priority in power distribution. The correlation analyses shows that G.R.A where wealthy people lives shares similar preference. Moreover, the eigenvalue analyses undertaken have ranked the substations in terms of priority listing.

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