A Statistical Application of Eigenvalue Theoretic Approach to Power Distribution Problems

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Abstract: **Power distribution problems such as outage and load losses have significant effects on sub stations. The perennial problem of electric power outage in Nigeria has adversely affected every sector of the nation economy and efforts must be made to fathom the technicalities associated with these outages and load losses. Spectral clustering is a popular data mining paradigm that is currently considered both as an effective practical tool for data analysis and also an active area of research. This study seeks to apply eigenvalue approach to determine the effects of each injection work station on Oshogbo transmission station. The process of obtaining eigenvalues and eigenvectors from power outages and loadlosses data made the eigenvector to appear like a dashboard where various interpretations were made.Our results show that Omuaran which is the nearest station to Oshogbo transmission centre with a distance of 3.7km has the highest eigenvalues (power outage=2.7054, load losses=3.1686) and appeared to be the hub of load losses and power outages in the region.**

Keywords: **Power outage; Principal component analysis (PCA); Spectral clustering; Eigenvalues.**

I. INTRODUCTION

Public power supply which involves transmission, and especially distribution in Nigeria like, in several other developing countries, is generally unsteady, a situation that is extensively attributable to various causes such as political disorientation, endemic corruption,inappropriate maintenance culture, wildfire, overload, among others and government's efforts to address this problem had yielded marginal success. Recently, in late March 2016, Nigeria had what has been described as total system collapse which resulted to 0MW output for the whole nation which has never happened in decades. According to [1], electric power supply is the most important commodity for national development adding that depriving people of electric power amounts to be cut off from the society. Several Studies have been taken to study power distribution problems especially on outage and loadlosses but none has been able to combine Principal component analysis and spectral clustering to obtain eigenvalues a feature which has made this study intriguing and distinctive. The Nigeria power transmission network is characterized by prolonged and frequent outages [2].Another study affirmed that power outages have assumed a very high embarrassing dimension in Nigeria [3].Similar studies on power outages in Nigeria [4], [5] and [6] have attributed the electric power outage to several factors and noted that the issue has remained a daunting challenge forNigeria.They said that the issue of power outage is not limited to Nigeria that similar eventshave taken place worldwide especially in some developing nations like Ivory coast, Brazil, Liberia, Guinea, Ghana, Peru etc.In Brazil,there was a massive black out in 2009 that lasted for hours.In U.S Canada on August 14,2003,more than 60000MW of load was lost thereby putting well over 50million consumers in blackout [7]. Most of the major factors affecting the availability of power supply could be grouped into two major classes. The first consists of those arising from policy actions which are deliberate in nature and they are usually taken to safeguard the equipment. They include such actions that are taken during emergency outages, planned or pre-arranged outages as well as load shedding. On the other hand, the other class includes those arising from forces external to the system and they include over-current, earthfault,high peak load as well as forced or automatic outages. However, some of the latter may lead to the former [8]. Power outages have assumed a very high embarrassing dimension in Nigeria. There are several areas of national life that power outage should never rear its ugly head but alas in Nigeria power outage for several days is common and could happen just anywhere. They further stated that in 2009, the presidential palace was not spared and power outage became so frequent that since then, the state house is powered 24hours with generators.Pablo[9] agreed that electricity plays a vital role in modern society. It is about the greatest invention of man. A country becomes a 24hours society because of the level of power (electricity available).A study [10] maintained that poor power supply and high level of unemployment are the major problems facing the Nigerian economy. It identified power outage as one of the major challenges confronting the Nigerian economy. It recognized electricity as a source of energy that is vital to the growth and development of any economy stating that erratic and inadequate power supply has been the major reason cited by many of the multinationals(Michelin, Dunlop Plc, Volkswagen Plc, PZ, Unilever).In India, a study concluded that power outages were a major factor in low capacity utilization industry. Recent articles have discussed the impact of power outages on economic activities in Nigeria. Notable among them are [11], [12] and [13].Electricity outage was ranked by very small firms among their top four constraints to expansion. Another study reported that on the expansion of small firmsyielded similar conclusion. Generally, this study on power outage with the obtainment of the eigenvalues has shown that the models are able to establish a merit order sequentiality of the distribution areas where the outages are pronounced and the mechanisms for the occurrence of these problems.

II. METHODOLOGY

The study employed Principal Component Analysis and Spectral Clustering. The data were obtained from Oshogbo transmission centre. The data were daily records on electricity supply outages dealing with various substations, durations of outages and load losses during outages between January and August 2011.The voltage level considered was 33kv from the national grid of 330kv/132kv.The area of study covered eight towns namely Oshogbo, Ilesa, Ilorin, Akure, Offa,Ife, Ondo and Omuaran. All these towns fall under three states which are Ondo,Osun and Kwarastates.

Principal Components Analysis

Principal Component Analysis (PCA) is a very popular data preprocessing technique that is commonly understood as a data-reduction and approximation method. Principal component analysis is a useful tool that has been widely used for the multivariate analysis of correlated variables and also to analyze data in various fields, such as in administration, social sciences, chemistry etc. The data matrix of table 1was fed into statistical XL software and the following output were obtained. The correlation matrix for the power outage data is shown in table 3

The data obtained are presented in a matrix form (8x8) for both outage and load losses.

Table 1: Data matrix of power outage

	Data matrix of power outage(kW)							
Work centre/month	Osogbo	Ilesa	ilorin	akure	offa	ife	ondo	Omuaran
Jan	441	357	349	600	0	414	76	577
Feb	472	514	167	487	20	411	205	515
March	668	790	192	697	40	614	155	692
April	524	757	195	490	27	591	162	798
May	513	585	205	383	10	612	238	950
June	557	506	1181	534	16	723	180	781
July	317	757	186	505	15	887	220	745
August	599	521	191	642	18	682	163	748

Table 2: Data matrix of load loss

Work centre/month	oshogbo	Ilesa	Ilorin	akure	Offa	Ife	Ondo	Omuaran
Jan	1338	127	1010	669	0	309	670	494
Feb	1460	193	763	463	32	190	399	284
March	1625	146	787	507	1503	207	460	495
April	1289	95	515	529	1207	264	736	424
May	1248	118	754	367	136	230	722	452
June	1344	94	795	329	993	232	712	428
July	974	119	684	447	414	304	695	477
August	1438	129	793	449	41	305	777	436

III. RESULTS AND DISCUSSION

Table 3

Correlation Matrix

	Oshogbo	Ilesa	Ilorin	akure	Offa	ife	Ondo	omuaran
Oshogbo	1.000	0.091	0.140	0.499	0.598	-0.175	-0.188	0.155
Ilesa	0.091	1.000	-0.340	0.013	0.757	0.528	0.412	0.356
Ilorin	0.140	-0.340	1.000	0.001	-0.182	0.201	-0.088	0.121
Akure	0.499	0.013	0.001	1.000	0.387	-0.028	-0.652	-0.431
Offa	0.598	0.757	-0.182	0.387	1.000	0.152	0.155	0.018
Ife	-0.175	0.528	0.201	-0.028	0.152	1.000	0.472	0.562
Ondo	-0.188	0.412	-0.088	-0.652	0.155	0.472	1.000	0.492
Omuaran	0.155	0.356	0.121	-0.431	0.018	0.562	0.492	1.000

The communalities for the power outage data is shown in Table 4

Table 4

Communalities

	Variable
Oshogbo	0.726
Ilesa	0.902
Ilorin	0.829
Akure	0.792
Offa	0.910
Ife	0.656
Ondo	0.762
Omuaran	0.723

The PCA factor loading for the power outage data is shown in table 4.5.The clustering of the factor loadings are shown in table 5.

Table 5

Unrotated Factor Loadings

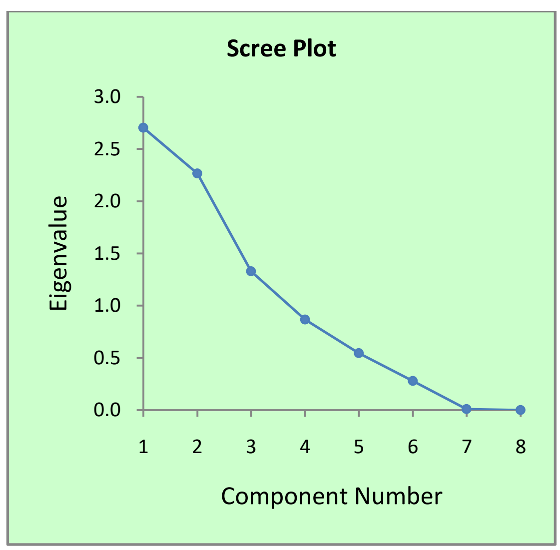
Variable	Factor 1	Factor 2	Factor 3
Oshogbo	-0.064	-0.751	0.397
Ilesa	0.763	-0.494	-0.276
Ilorin	-0.100	0.168	0.889
Akure	-0.441	-0.759	0.148
Offa	0.375	-0.869	-0.116
Ife	0.743	0.004	0.322
Ondo	0.819	0.280	-0.116
Omuaran	0.743	0.141	0.390

The clustering of the factor loading is shown in table 6

Table 6

Varimax Rotated Factor Loadings

Variable	Factor 1	Factor 2	Factor 3
Oshogbo	0.746	0.295	0.304
Ilesa	0.813	0.165	-0.475
Ilorin	0.122	0.766	-0.299
Akure	0.024	0.807	0.030
Offa	0.137	-0.205	0.950
Ife	-0.824	0.420	-0.184
Ondo	-0.930	-0.097	0.019
omuaran	-0.581	0.492	0.508



The scree plot of power outage data is shown in figure 3.

Ondo\Akure-ondo and akure are fairly equidistant from Oshogbo, the main distribution centre and therefore has the same distribution characteristics and consequently positively correlated in terms of power distribution losses. Correlation matrix of table 4.3 shows offa\Ilesa, osogbo\offa shares the same characteristics. Their respective correlation coefficients are:

Offa\ilesa = 0.757

Ondo\akure = 0.652

Oshogbo\offa = 0.598

Generally, the communalities are relatively high indicating that the towns share a common variance of power outages. Put simply, the towns witness a similar regime of power losses variability.

|Table 5 and 6 depict the unrotated and rotated factor loadings respectively. The latter reflects the fact that the three factors are unique quite unlike the former. And by uniqueness, we mean that each variable belongs to one and only one factor which may not be the case for the unrotated factor loadings. The import is that the rotated factor loading was successful in achieving parsimony by summarizing the eight variables into three dimensions only.

Figure 3 represents the screeplot. The bottomline of this plot is that it gives the minimum eigenvalue (=1) for which a maximum number of factors can be extracted. And in this particular case, λ=1 and number of factors equals three (3).

The data matrix of table 2 was fed into statistical XL software and the following outputs were obtained.

The correlation matrix for the load losses is shown in Table 7

Table 7

Correlation Matrix

	oshogbo	Ilesa	Ilorin	akure	Offa	ife	ondo	omuaran
Oshogbo	1.000	0.450	0.286	0.156	0.271	-0.526	-0.541	-0.195
Ilesa	0.450	1.000	0.268	0.177	-0.359	-0.460	-0.841	-0.584
Ilorin	0.286	0.268	1.000	0.331	-0.453	0.156	-0.146	0.232
Akure	0.156	0.177	0.331	1.000	-0.086	0.395	-0.159	0.256
Offa	0.271	-0.359	-0.453	-0.086	1.000	-0.340	-0.135	0.277
Ife	-0.526	-0.460	0.156	0.395	-0.340	1.000	0.714	0.531
Ondo	-0.541	-0.841	-0.146	-0.159	-0.135	0.714	1.000	0.451
Omuaran	-0.195	-0.584	0.232	0.256	0.277	0.531	0.451	1.000

The communalities for the load losses data is shown in Table 8

Table 8

Communalities

	Variable
oshogbo	0.736
Ilesa	0.914
Ilorin	0.691
Akure	0.652
Offa	0.963
Ife	0.888
Ondo	0.875
omuaran	0.837

The PCA factor loadings for the load losses data is shown in table 9

Table 9

Unrotated Factor Loadings

Variable	Factor 1	Factor 2	Factor 3
oshogbo	0.681	0.077	0.516
Ilesa	0.860	0.366	-0.201
Ilorin	0.120	0.808	0.157
akure	-0.022	0.675	0.442
Offa	0.017	-0.668	0.719
Ife	-0.812	0.475	-0.059
Ondo	-0.918	-0.070	-0.167
omuaran	-0.670	0.174	0.599

The clustering of the factor loadings are shown in Tabe 10

Varimax Rotated Factor Loadings

Variable	Factor 1	Factor 2	Factor 3
oshogbo	0.746	0.295	0.304

Ilesa	0.813	0.165	-0.475
Ilorin	0.122	0.766	-0.299
akure	0.024	0.807	0.030
Offa	0.137	-0.205	0.950
Ife	-0.824	0.420	-0.184
Ondo	-0.930	-0.097	0.019
Omuaran	-0.581	0.492	0.508

The correlation between ondo and ife is 0.714. on the one hand, the correlation between ondo and ilesa is 0.841 indicating that on account of the long distances which the transmission of power undergo with losses are exceptionally high.

Table 8 shows the communalities for load losses among the towns studied. Like the power outage case, table 9 and 10 depict the unrotated and varimax rotated factors for load losses. Again, and as explained earlier under power outages, figure 3 depicts the scree plot for power losses. Three factors corresponding to λ=1were extracted.

The screeplot of load losses is shown in figure 3

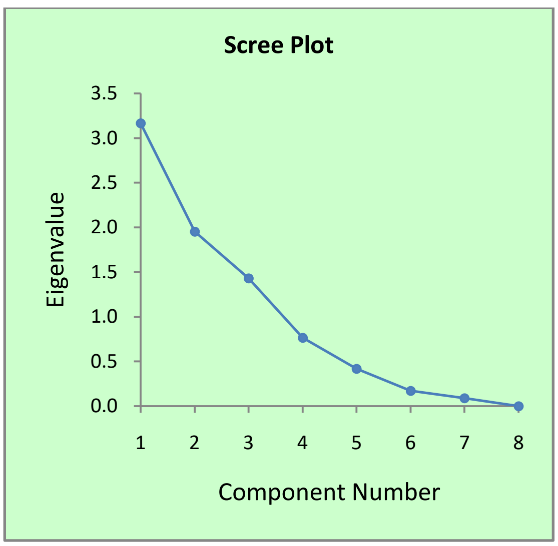


Figure 3

The power outage column eigenvector for Oshogbo showed that Offa Substation power outages have dominating negative effect (-0.5186) on Oshogbo power outages. This indicated that power supply at Oshogbo was boosted by the corresponding power outage in Offa. Likewise, the power outage column eigen vector for Ondo showed that Offa substation power outages have dominating negative effect(-0.5775) on Ondo power outages .This indicated that power supply at Ondo was boosted by the corresponding power outage in Offa.

The eigen values for power outages during the period is shown below.

$$\lambda = \begin{bmatrix} -0.0006 \\ 0.0107 \\ 0.2774 \\ 0.5444 \\ 0.8670 \\ 1.3291 \\ 2.2665 \\ 2.7054 \end{bmatrix} \begin{bmatrix} Oshogbo \\ Ilesha \\ Ilorin \\ Akure \\ Offa \\ Ife \\ Ondo \\ Omuaran \end{bmatrix}$$

The eigenvalue for omuaran substationoutages (2.7054) has the highest value which indicated that the record for this substation is associated with the highest level of Least Square Error for the outage data mining process.

The eigenvalue for load losses during the period is shown below.

$$\lambda = \begin{bmatrix} -0.002 \\ 0.0886 \\ 0.1723 \\ 0.4196 \\ 0.7632 \\ 1.4329 \\ 1.9550 \\ 3.1686 \end{bmatrix} \begin{bmatrix} Oshogbo \\ Ilesha \\ Ilorin \\ Akure \\ Offa \\ Ife \\ Ondo \\ Omuaran \end{bmatrix}$$

The eigenvalue and eigenvector approach used in the analysis of both power outage and load losses data facilitated the understanding of the relationship that exists among various sub-stations under the Oshogbo transmission/injection station.Each sub-station has a specified rate of supply /loading that comes to it. The eigenvector represents a grid-like relationship for the distribution sub-stations. It gives a measure of one substation relative to Oshogbo.MATLAB software was used as a computational aid to facilitate the resolution of the correlation matrix which resulted into the obtained eigenvector and eigenvalues. Furthermore, Omuaran sub-station, which has the highest eigenvalue (power outage=2.7054,load losses=3.1686) appeared to be the hub of load losses and power outages in the region.

V. CONCLUSION

The models are able to establish a merit order sequentiality of the distribution areas where the outages are pronounced and the mechanisms for the occurrence of these problems. The process of obtaining eigenvalues and eigenvectors from power outages and load losses data made the eigenvector to appear like a dash board frame where various interpretations can be deduced has been confirmed.This makes us to know the effect that each substation has on Oshogbo distribution centre. It has given us the opportunity to know the way to channel distribution lines to these substations by considering their distance from the supply and also by their position on the distribution grid that was produced in the course of this study.

RECOMMENDATION

Further study in this area should research into losses and power outages from the transmission lines. i. e 330kv using the same approach.

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