NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Factorial Study of Factors Affecting Performance of Gas Power Plant in Nigeria

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Article Info

Received 07 November 2020
Revised 08 December 2020
Accepted 18 December 2020
Available online 24 December 2020

Keywords:
Power plant, Factorial Analysis, KCC, Critical Factors, Gas Turbine.

Crossref NIPES JOURNALS

https://doi.org/10.37933/nipes.e/2.2020.7

https://nipesjournals.org.ng

Abstract

A computational study of various factors affecting proper functioning of a gas power plant located in the Niger Delta region of Nigeria is presented in this research paper. This study aims to identify all possible cause of non optimum performance of gas power and condense these causes into a fewer factor while still retaining the meaning of each causes. Statistical analyses were done on the identified variables using Kendall's coefficient of concordance and principal component of analysis. From the investigation, 64% of the judges agreed on the rating of identified variables and a new set of seven principal components were formulated from the forty three identified variables. It is observed that factor one which is the principal factor houses both the thermodynamic parameters and reliability components, thus making it a prime factor to note.

1.Introduction

One of the notable infrastructural paucity in Nigeria is in the area of power. The electricity demand in Nigeria far outstrips the supply and the supply is epileptic in nature. The country is faced with acute electricity problems, which is hindering its development despite the availability of vast natural resources in the country. It is widely accepted that there is a strong correlation between socio-economic development and the availability of electricity [1]. The Nigerian electric power has been so epileptic that the Vanguard newspaper of 23rd, February 2013, reported that the Manufacturer Association of Nigeria (MAN) and the National Association of Small Scale Industries (NASSI) estimated that their members spend an average of two Billion Naira weekly on self-powered generation. The little power available is distributed to few locations. The enormous energy demand in technological and social – economic development has called for urgent attention in the power sector. Nigeria Government has set ambitious goals for its socio-economic development, developing a unified plan of action on all issues relating to repositioning Nigeria from its current position in world's GDP ranking to be among the top 20 most developed countries of the world [2].

To achieve adequate power supply, three critical activities must be achieved. Firstly, adequate power must be generated; secondly, the power must be transmitted to all parts of the country; and thirdly, it must be distributed to the end user [3]. In view of this, President Olusegun Obasanjo's led government in 2005, launched the power transformation journey. The sole provider of electricity then which was National Electric Power Authority (NEPA), was replaced by the Power Holding Company of Nigeria (PHCN). PHCN was later unbundled into six generation companies, eleven distribution companies (DisCos) and the Transmission Company of Nigeria. Independent bodies such as the Nigerian Electricity Regulatory Commission (NERC) and the Rural Electrification Agency (REA) were also formed to oversee progress and maintain transparency. In 2010, a Roadmap for Power Sector Reform was developed, which privatised the generation and distribution companies, while transmission of electricity remained state-owned. In addition, the Nigeria Bulk

Electricity Trading Plc. (NBET) was formed to engage in the purchase and resale of electric power and ancillary services from independent power producers and the successor generation companies. The power sector reforms are anchored on but not limited to the construction of power plants that use of natural gas for power generation in order to meet the needs of the country.

The effective utilisation of gas in power station is one of the main determining factors of performance of power station capacity utilisation. Performance indices in generating companies show an underutilisation of installed capacity of these power plants. While the Nigeria National Petroleum Corporation quarterly gives report on gas supply to power station and expected power to be generated [9]. Also, the Energy Commission of Nigeria [2], projected electricity demand and natural gas needed for it to be accomplish. But after careful study, there are some challenges that affect effective power generation, transmission and distribution in Nigeria. This study is intended to investigate, identify and condense these factors affecting gas power plant performance in Nigeria into fewer ones while the initial meaning is retained.

2. Methodology

This section presents the procedures employed in our investigation.

2.1 Research Design

The main focus of this research work is to identify different variables that affect the efficient running of gas power plants and the inter correlation among these variables. Statistical tools such as Kendall's coefficient of concordance and Principal Component Analysis would be deployed to know the level of association and agreement of variables among experts in the field of power plants and also, to identify the variables with the most magnitude among an already grouped factors.

2.2 Design of Questionnaire

The questionnaire used in the study was designed from the data obtained from the NIPP plants, power stations and relevant literature. Forty – three (43) variables were identified and used to design questionnaires with five – point Likert's attitudinal scale whose dimensions include - strongly agree, agree, undecided, disagree, and strongly disagree that was administered to one hundred (100) respondents in generation sector of power stations. The questionnaires were administered to respondents who have over fifteen years working experienced in gas power plants. Respondents' responses were transposed into metric variables. Out of the 150 set of the questionnaire administered to knowledgeable respondents, 100 were retrieved. This is about seventy-nine percent (95%) success. Respondent's scores were then collated as data matrix as shown in Appendix 1. The data were fed into StatistiXL software that gave the following output:

i. scree plot
ii. eigen value and eigen vectors
iii. factor plot (factor loadings)
iv. descriptive statistics result and
v. case wise factor scores (correlation matrix)

The mathematical theories that govern the software statistical analysis are sketched hereunder model employed. Also, the research hypothesis were tested using same 43 variables and administered to 13 highly experienced engineers involved in maintenance, operation and performance in power generation stations for rating.

2.3 Model employed

Suitable statistical models will be used to achieve the objectives of the research and these include: Kendall's Coefficient of Concordance and The Principal Component Analysis.

2.3.1. **Kendall Coefficient of Concordance**

a. Let N = number of scale items to be ranked and let k = the number of judges assigning ranks.
b. Input the observed rank into K*N matrix
c. For each entity obtain R_j, which is the total scores of each of the scale item
d. Obtain the mean of the various R_j's, where j refers to the variable response or stimulus from the judges on scale item, i
e. Obtain the deviation of every R_j from the calculated mean of R_j
f. Obtain the square of the deviation of each of the scale items
g. The Kendall Coefficient of Concordance (W), which measures the degree of agreement between the judges is obtained from the Equation (1)

$$W = \frac{12S}{K^2(N^3-N)} \quad (1)$$

Where $S = \sum(R_j - \sum R_j/\mathrm{N})^2$ = Rank variance (2)

2.3.2The abridge theory of the application of the Principal Component Analysis (PCA)

Let X_{ij} and Y_{ij} represent a pair of variables in the data matrix. Define column mean as

$$\bar{X}_{.j} = \sum_{i=j}^{N} \frac{X_{ij}}{n_j} \quad (3)$$

and

$$\bar{Y}_{.j} = \sum_{i=j}^{N} \frac{Y_{ij}}{n_j} \quad (4)$$

Then $x = X_{ij} - \bar{X}_{.j}$ and

$y = Y_{ij} - \bar{Y}_{.j}$,

where i and j refers to the state of the matrix, x and y refers to the respective mean deviation or deviation from the mean.

Hence, the correlation coefficient, r_{ij} is defined as

$$r_{ij} = \frac{\sum xy}{\sqrt{(\sum x^2).(\sum y^2)}} \quad (5)$$

$x = X_{ij} - \bar{X}_{.j}$

$y = Y_{ij} - \bar{Y}_{.j}$,

$$\bar{X}_{.j} = \sum_{i=j}^{N} \frac{X_{ij}}{n_j}$$

$$\bar{Y}_{.j} = \sum_{i=j}^{N} \frac{Y_{ij}}{n_j},$$

When r_{ij} is computed for every pair from the whole lot of ${}^{n}C_2 = \frac{n!}{(n-2)!2!}$. (6)

3.Results and Discussion

This section focuses on presentation of data for the research and gives a detail mathematical analysis that give rise to the result.

3.1 Kendall's Coefficient of Concordance Analysis

The forty three scale items were referred to thirteen judges who are well-informed on the subject matter to rank them in Merit Order Sequentially. Accordingly, the ranking is depicted in Table 1.

Table 1: Ranking of scale items

S/N	Rj	Variable	S/N	Rj	Variable
1	46	Working fluid absolute temperature	23	321	Maintenance shutdown windows
2	76	Plant ambient condition	24	329	Plant design
3	77	Operating conditions	25	329	Spare parts
4	77	Gas supply and quality	26	335	Investment funding
5	91	Gas transmission network	27	337	High voltage transmission
6	92	Gas flow rate	28	340	Vandalisation of transmission line
7	108	Enstructured spray cooler	29	342	Generator transformer
8	120	Compressor compression ratio	30	348	Human capacity development
9	172	Plant capacity	31	372	Government bureaucratic
10	180	Condition monitoring	32	360	Government polices
11	193	Frequent equipment breakdown	33	391	Act of God
12	195	Gas development plan	34	397	Staff morale
13	200	Aging infrastructure	35	403	Workers
14	206	Pipeline vandalisation	36	433	Cooling Fluid
15	213	Facilities maintenance and scheduling	37	436	Tariffs
16	221	Regulation/regulators	38	442	Labour issues
17	234	Grid capacity	39	466	Foreign Exchange
18	254	Equipment obsolete	40	467	Manpower Strength
19	264	Transmission network coverage	41	476	Moral Torpidity
20	296	Efficient technology	42	478	Community
21	304	Plant management	43	491	Insecurity
22	306	Plant Logistics			

Kendall coefficient of concordance is given by:

$$W = \frac{S}{\frac{1}{12}K^2(N^3 - N)} \quad (7)$$

$$S = \sum \left(R_j - \frac{\sum Rj}{N} \right)^2 \quad (8)$$

R_j = Colum sum of ranks = 12240
N = 43
S = Variance
K = Number of Judges = 13
From factor Ranking Matrix
$\sum R_j$ = 24449
$\frac{\sum Rj}{N} = \frac{12240}{43}$ = 284.65
$S = \sum(Rj - \frac{\sum Rj}{N})^2$ = 715495.8
Therefore S= 715495.8
$W = \frac{715495.8}{\frac{1}{12}13^2(43^3-43)}$ = 0.64
Also
χ^2 = K(N-1)W = 13(43-1)0.64
=349.44
(N – 1) = degree of freedom
H_o: The rankings of the 13 judges are discordant
H_1: The judges are using the same standard in ranking
At α = 0.05 significant level, χ^2 = 58.12
Since χ^2_{cal} = 349.44 > $\chi^2_{tab.}$ = 58.12, we fail to accept the null hypothesis (H_0) and therefore conclude that the judges ranking of the 43 scale items were consistent.
The plots of the extracted forty three factors were generated using StatisXL software shown in Figure 1.

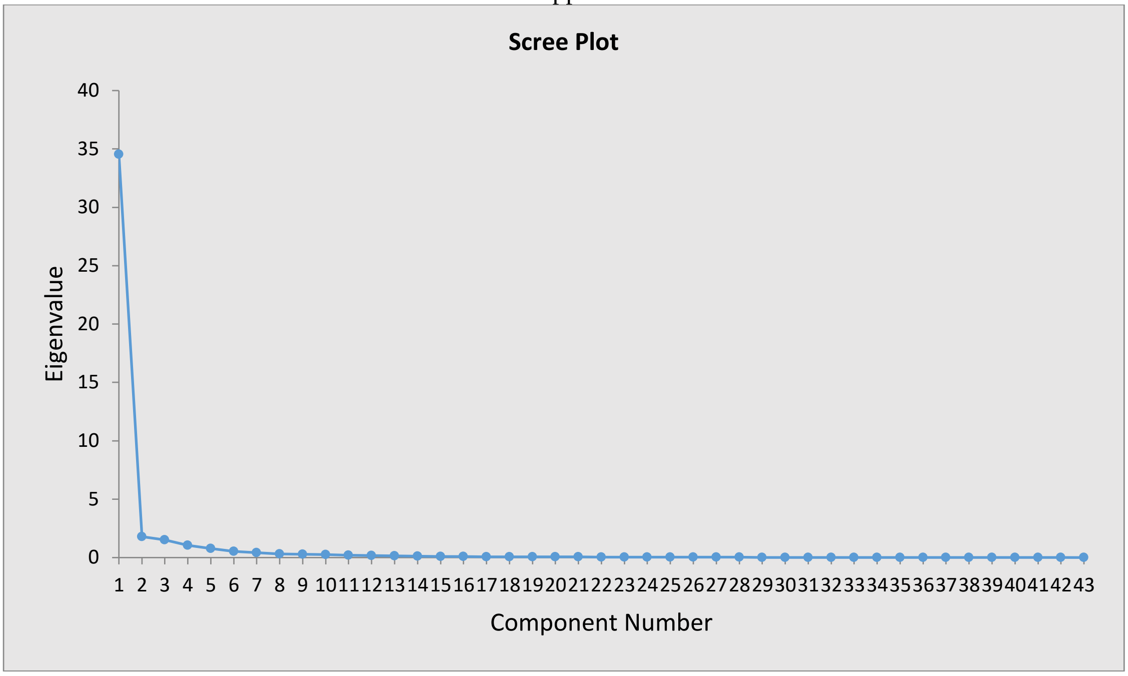

Figure 1. Scree plot of the factors

Figure 1 shows the eigenvalue. It's obvious from the scree plot that at eigenvalue of 1, and component number 7, the curvity tends to flatten out, suggesting that seven factors extracted are adequate.

3.2 Varimax factor loading

The factors were extracted by statistiXL software, having fed the collated data matrix into it. Factors are extracted at the eigenvalues greater than 1.

Table 2 Varimax factor loading

s/n	Variable	F1	F2	F3	F4	F5	F6	F7
1	Plant ambient conditions	0.469	0.357	0.372	0.365	0.149	0.018	**0.595**
2	Operating Conditions	**0.799**	0.445	0.179	0.272	0.093	0.041	0.022
3	Labour/union issues	0.438	**0.759**	0.234	0.259	0.106	0.119	0.182
4	Generator Transformer	**0.555**	0.388	0.175	0.5	0.206	0.281	0.182
5	Workers	0.514	**0.724**	0.13	0.285	0.11	0.099	0.105
6	Society/community	0.52	**0.729**	0.251	0.254	0.087	0.075	0.061
7	Cooling fluid	**0.793**	0.441	0.266	0.205	0.087	0.055	0.091
8	Foreign exchange	0.493	**0.718**	0.362	0.184	0.065	0.09	0.096
9	Logistics	**0.703**	0.345	0.304	0.282	0.135	0.091	0.299
10	Transmission Network coverage	0.496	0.521	0.309	**0.565**	0.016	-0.019	0.094
11	Efficient technology	**0.804**	0.394	0.272	0.193	0.146	0.146	0.1
12	Gas supply and Quality	0.563	0.295	**0.667**	0.198	0.167	0.096	0.049
13	Grid capacity	0.374	0.557	0.237	**0.614**	0.191	0.118	0.148
14	Government policies	0.367	**0.757**	0.151	0.372	0.123	0.109	0.213
15	Funding/Investment	0.303	**0.723**	0.365	0.118	0.22	0.32	-0.024
16	Equipment obsolescence	**0.788**	0.407	0.201	0.24	0.175	0.12	0.153
17	Maintenance shutdown windows	**0.593**	0.45	0.344	0.341	0.173	0.244	-0.031
18	Compressor compression ratio	0.336	0.549	0.276	0.115	0.237	**0.661**	0.031
19	High voltage Transformer	**0.735**	0.441	0.257	0.222	0.176	0.175	0.021
20	Spare parts	**0.772**	0.482	0.182	0.264	0.119	0.047	0.069
21	Regulations/Regulators	0.594	0.315	**0.616**	0.066	0.197	0.173	0.047
22	Staff morale/ Remuneration	0.494	**0.755**	0.148	0.291	0.06	0.097	0.136
23	Pipe line vandalism	0.359	0.511	**0.552**	0.34	0.22	0.208	0.06
24	Aging Infrastructure	**0.584**	0.428	0.178	0.526	0.14	0.064	0.108
25	Man power strength	0.378	**0.736**	0.463	0.137	0.102	0.071	-0.014
26	Conditioned monitoring	**0.719**	0.352	0.369	0.237	0.186	0.169	0.163

27	Plant capacity	0.246	**0.555**	0.345	0.616	0.232	0.167	0.047
28	Vandalization of transmission line	0.372	**0.687**	0.22	0.346	0.205	0.235	0.109
29	Frequent Equipment breakdown	**0.588**	0.317	0.473	0.342	0.177	0.06	0.178
30	Government Bureaucracy	0.366	**0.675**	0.18	0.44	0.179	0.095	0.133
31	Act of God	0.319	**0.707**	0.513	0.142	0.123	0.162	0.07
32	Facilities maintenance and schedule	**0.689**	0.552	0.204	0.197	0.183	0.121	0.135
33	Gas flow rate	0.231	0.285	**0.844**	0.231	0.225	0.06	0.142
34	Working fluid absolute temperature	**0.81**	0.396	0.265	0.219	0.14	0.142	0.019
35	Insecurity	0.375	**0.806**	0.25	0.281	0.118	0.104	0.118
36	Gas developmental plan	0.439	0.425	**0.476**	0.402	0.224	0.246	0.117
37	Moral torpidity	0.526	**0.686**	0.27	0.245	0.076	0.015	0.031
38	Tariffs	0.482	**0.674**	0.242	0.277	0.137	0.242	0.032
39	Enstructured spray cooler	**0.701**	0.37	0.379	0.165	0.19	0.215	0.069
40	Plant management	0.493	**0.716**	0.273	0.231	0.1	0.138	0.111
41	Plant design	**0.62**	0.333	0.416	0.262	0.194	0.184	0.288
42	Gas transmission network	0.488	0.504	0.26	**0.609**	0.004	-0.028	0.119
43	Human capacity development	0.267	0.161	0.312	0.136	**0.876**	0.117	0.065

3.3 Factor Interpretation

After the identification of 43 variables as possible weighty factors to be considered in justifying gas to power generation relationship in NIPP plant, and the subsequent administration of these variables in likert questionnaires form to respondents, a 43 × 100 data matrix were collated. With 21 iterations, seven (7) factors F1 to F7 were extracted. Convincingly, judging from the table 1 to 7, factor 1 is regarded as a principal factor and hence labelled facilities monitoring; F2 is labelled socio – fiscal and technical concern; F3 is labelled fuelling conditions; F4 is labelled System Score; F5, F6 and lastly F7 are lone factor in their domain and clustered to obtain Socio – technical system.

Table **3. Factor- variable classification**
Cluster 1: Facilities Monitoring.

S/N	**Variable**	**Factor 1**
1	Working Fluid absolute temperature	**0.810**
2	Efficient Technology	**0.804**
3	Operating Conditions	**0.799**
4	Cooling fluid	**0.793**
5	Equipment obsolescence	**0.788**
6	High voltage Transformer	**0.735**
7	Spare parts	**0.722**
8	Conditioned monitoring	**0.719**
9	Logistics	**0.703**
10	Enstructured spray cooler	**0.701**
11	Facilities maintenance and schedule	**0.689**
12	Plant design	**0.620**
13	Maintenance shutdown windows	**0.593**
14	Frequent Equipment breakdown	**0.588**

15	Aging Infrastructure	**0.584**
16	Generator Transformer	**0.555**

Sixteen (16) variables were clustered. From the table, working fluid (air) absolute temperature had a factor loading of 0.810 thus making it the most intrinsic factor. Also, from the table, the least scale item was the generator transformer with factor loading 0.555, all the other variables had an advance effects on the general performance of the gas power plant be it plant efficiency, capacity utilisation, plant availability or even operational reliability.

Variables such as working fluid absolute temperature, efficient technology, operating conditions, cooling fluid, high voltage transformer, enstructured spray cooler and plant design had direct relationship on plant efficiency. Also, capacity utilisation was seen to have its root in plant design, high voltage transformer and generator transformer. Furthermore, facilities maintenance and schedule and conditioned monitoring are determinant in considering plant availability. Lastly, operational reliability was ensured with proper consideration for aging infrastructure, frequent equipment breakdown, maintenance shut down windows, logistics, spare plants and equipment obsolescence.

Table **4. Socio – Fiscal and Technical concern**

Cluster 2: Socio – Fiscal and Technical concern.

S/N	**Variable**	**Factor 2**
1	Insecurity	**0.806**
2	Labour/union issues	**0.759**
3	Government policies	**0.757**
4	Staff morale/ Remuneration	**0.755**
5	Man power strength	**0.736**
6	Society/Community	**0.729**
7	Workers	**0.724**
8	Funding/Investment	**0.723**
9	Foreign exchange	**0.718**
10	Plant management	**0.716**
11	Act of God	**0.707**
12	Vandalization of transmission line	**0.687**
13	Moral torbidity	**0.686**
14	Government Bureaucracy	**0.675**
15	Tariffs	**0.674**

The next cluster was tagged socio – fiscal and technical concern as shown in Table 4. Fifteen (15) variables were under this assemblage with insecurity having the most influential factor loading of 0.806. Although insecurity, labour/issues, Government policies and others under this factors might not per se have a direct technical effect on plant gas to power utilisation, but any attempt to

undermine any of these variables may gradually or drastically affect the performance of plant gas utilisation efficiency as no principal factor can stand on its own without the support or gate pass from any of these other factors in cluster 2.
The next factor is tagged fuel condition.

Table 5. Fuel Condition
Cluster 3: Fuel Condition

S/N	Variable	Factor 3
1	Gas flow rate	**0.844**
2	Gas supply and quality	**0.667**
3	Regulations/Regulators	**0.616**
4	Pipe line vandalism	**0.552**
5	Gas development plan	**0.476**

Five (5) variables were clustered with gas flow rate having the most factor loading of 0.844. A gas power plant will tends to have high efficiency in gas utilisation to power generation if the gas supply from its source is maintained optimally within the set standard of pressure as set by the OEM. With a good gas developmental plan that ensures constant delivery of quality gas in right parameters, there will be optimum gas utilisation, thereby leading to better performance of gas power plants.

Table 6. System Scope
Cluster 4: System Scope

S/N	Variable	Factor 4
1	Plant capacity	**0.616**
2	Grid capacity	**0.614**
3	Gas transmission network	**0.609**
4	Transmission Network coverage	**0.565**

In this compilation four variables (plant capacity, grid capacity, gas transmission network and transmission network coverage) are clustered and they are tagged system scope. Plant capacity with loading factor (0.616) is most influential variable. The utilisation of gas in power plant is determined by its design capacity which also takes into cognise the gas transmission network in place. The grid capacity and transmission network coverage plays an influential role in the daily power generation, as generation must be within the confinement of the grid allowable capacity which is necessitated by its coverage.
The last three factors F5, F6 and F7 are secluded in their group with each having a factor loading of (0.876), (0.661) and (0.595) respectively.

Table 7. Variables

S/N	Variable	Factor 5
1	Human capacity development	**0.876**

S/N	Variable	Factor 6
1	Compressor compression ratio	**0.661**

S/N	Variable	Factor 7
1	Plant ambient Conditions	**0.595**

These lone factors can be clustered to obtain technical system.

Table 8. Technical System
Cluster 5: Technical System

S/N	Variable	Factor
1	Human capacity development	**0.876**
2	Compressor compression ratio	**0.661**
3	Plant ambient Conditions	**0.595**

They are jointly but exclusively explain as thus: Expanding the human/workers skills through training and re – training on the job; recent technological approaches tends to have corresponding effects on power generation. More also, the efficient working of the compressor which engenders the optimum compression of the working fluid is also a key in efficient working of gas power plant. Lastly, the environmental condition of power plants is highly considered in sighting gas power station.
Several research such as [4], [14], [15] had recommended efficient operation and maintenance, air inlet cooling system and better spare parts management as factors that can engender high performance of gas power plant, good as it may, in this study, the facilities monitoring encompasses these factors and further reveal other factors which are interpreted according to cluster 1 to 5.

4.Conclusion

The Kendall's Coefficient of Concordance w, was found to be 0.64 is considered a middling, suggesting that there was agreement among the judges that ranked the variables. Consequently, a null hypothesis claiming that the ranking of the range of factors by thirteen (13) judges is discordant was rejected at a p-value of 0.05, thus suggesting that the computed index of consistent ranking (coefficient of concordance W = 0.64) is middling inter correlation. The implication of the re-ordering of these variables by the judges is that the problems can be hierarchically arranged in terms of management attention. The ranking of the scale items imply that management should pay more attention to the issue raised according to their severity. This will offer a veritable framework for achieving productivity in gas power plants. The questionnaire couched in 5-point Rensis Likert's attitudinal scale was successful in extracting the responses from the 100 respondent's score into data matrix. The PCA deployed was successful in achieving parsimony by clustering a plethora of forty-three (43) variables into seven (7) factors and subsequently further reduced to (5) collections; facilities monitoring, socio – fiscal and technical concern, fuel condition, system scope and technical system.

References

[1] A. S. Sambo (2010). "Electricity Generation for Sustainable Development in Nigeria: Status and the Way Forward". Lecture Delivered to Participants of Exec. Intelligence. Management Course 3, Institute for Security Studies, Abuja, 5th August, 2010.
[2] ECN/EPA/2014/01
[3] A.S. Sambo (2008). Matching Electricity Supply with Demand in Nigeria. Fourth Quarter 2008. International Association for Energy Economics.
[4] Isaac F.O and Obodeh .O (2011) .Performance Analysis for Sapele Power Station; Case Study for Nigeria. Journal of Engineering Trends in Engineering and Applied Science (JETEAS)2(1):166-177.
[5] NNPC | Monthly Financial and Operations Report March 2017 www.nnpcgroup.com |
[6] Chidozie Chukwuemeka Nwobi-Okoye and Anthony Clement Igboanugo. (2015). Performance appraisal of gas based electric power generation system using transfer function modelling Ain Shams Engineering Journal (2015) 6, 541–551
[7] Adenikinju, Adeola F. (1998). Productivity Growth and energy Consumption in the Nigerian Manufacturing Sector: A panel data analysis. Energy Policy, 26, 3, 199-205.
[8] A. H.Sule.(2015) Major Factors Affecting Electricity Generation, Transmission And Distribution In Nigeria, international journal of Engineering and mathematical intelligence , vol . 1 Nos 1& 3,2
[9] NGC, 2008 Report.
[10] Kadiri Kamoru Oluwatoyin, Agbaje Michael Oluwasegun, and A. O. Alabi. Issues and Challenges of Ownership and Privatization of Power Stations in Nigeria'" Journal of Scientific Research & Reports 8(3): 1-8, 2015; Article no.JSRR.18296 ISSN: 2320-0227.
[11] F.O. Isaac and O. Obodeh (2011) .Performance Analysis for Sapele Power Station; Case Study for Nigeria. Journal of Engineering Trends in Engineering and Applied Science (JETEAS)2(1):166-177.
[12] J. Y. Oricha, G. A. Olarinoye. Analysis of Interrelated Factors Affecting Efficiency and Stability of Power Supply in Nigeria "International Journal of Energy Engineering 2012, 2(1): 1-8 DOI: 10.5923/j.ijee.20120201.01
[13] Momodu, A. S., Oyebisi, T. O. and Obilade, T. O. Modelling the Nigeria's Electric Power System to Evaluate its Long-Term Performance "International Journal of Technology, Policy and Management, Vol 12 No 1, 2012
[14] S.O. Oyedepo , R.O. Fagbenle , S.S. Adefila , S.A. Adavbiele Performance evaluation and economic analysis of a gas turbine power plant in Nigeria" Energy Conversion and Management 79 (2014) 431–440
[15] Sunday Olayinka Oyedepo, Richard Olayiwola Fagbenle & Samuel Sunday Adefila(2015).Assessment of performance indices of selected gas turbine power plants in Nigeria Energy Science & Engineering published by the Society of Chemical Industry and John Wiley & Sons Ltd.