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Selection of Suitable Power Plants in Two Regions of Nigeria

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Abstract
Technique of Order Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision making technique, was applied in the selection of power plants for installation in the Niger Delta region and the North-East region of Nigeria. The power plants considered are Gas turbine power plant, steam turbine power plant, combined cycle power plant, hydro power plant, wind turbine energy system and solar PV systems. Seven attributes criteria were used in the selection process. The criteria are installation cost, operation and maintenance cost, availability of primary energy source, consistency of primary energy source, environmental impact of system operation, package sizes and ease of deployment. The attributes were assigned weights obtained from experts in the field. A decision matrix was formed and the entries in the matrix were obtained from experts. The TOPSIS scores obtained from the analysis was used in judging the level of suitability of installing a particular power production system. In the Niger Delta region, the TOPSIS score for the least favourable power plant system (steam turbine power plant) is 0.459 while that for the most favourable power plant system (combined cycle power plant) is 0.712. In the North-East region, the least favourable power plant (steam turbine power plant) has a TOPSIS score of 0.374 while the most favourable power plant to be operated (hydro power plant) has a TOPSIS score of 0.615. Generally, it is more favourable to operate renewable energy systems for power production in the North-East region while the Niger Delta region is more suitable for installing thermal power plants.

1. INTRODUCTION

Electrical power or electricity is a basic requirement for the survival and growth of any nation. It is produced via different means. The means of producing electrical power can categorized as conventional and non-conventional [1]. The conventional means of electricity production include the use of power plants such as gas turbine power plants, steam turbine power plants (using coal, natural gas or nuclear energy as source of heat), combined cycle power and hydro power plants using dams. Diesel engine was predominantly used for power production on large scale before the usage of gas turbines. It can as well be termed conventional means of power production. The diesel engine serves as a means of power production (either as standby or main source) in many institutions and companies in Nigeria. The nonconventional means of power production do involve renewable energy resources. Power production via solar photovoltaic (PV), wind turbines and direct energy conversion means can be termed non-conventional.

Nigeria depends largely on gas turbines and hydro power plants for power production. But the amount of power produced is insufficient. Also there seems to be poor transmission infrastructure, coupled with poor distribution infrastructure. There are a lot of problems in the sector which have been addressed by several researchers [2-5]

Aside the problems in the power sector identified by the various researchers, the low usage of renewable energy resources for power production has been a concern considering the global call for cutting down the usage of fossil fuels. Wind energy and solar energy can be harnessed in large scale for power production in various locations in Nigeria. Such power may or may not be connected to the national grid. The gas turbine power plants are concentrated in the Niger Delta region of the country. This is because of the large deposit of natural gas (which serves as the fuel) in the region. Combined cycle can equally be exploited. Some gas turbine power plants are in other regions of the country. This will require building long gas pipelines which cost may be enough to build new plants in the Niger Delta region. If such is the case, the power produced can be transmitted to other regions via the national grid. In addition, wind and solar energy systems can be exploited in various locations in the Niger Delta region. The hydro power plants are found mostly in the North central region of the country. The North-West and North- Eastern regions are blessed with high wind speeds and high solar radiation values. Wind turbines and solar PV systems installations appear attractive.

In this research, the suitability of establishing different power plants for the North-Eastern and the Niger Delta region are analyzed using a number of criteria. The power plants considered are gas turbine power plant, steam turbine power plant, combined cycle power plant, hydro power plant, wind turbines and solar PV systems. Since there a number of power generation techniques and the various techniques are to be selected based on a number of criteria, a multi-criteria decision making technique should be exploited for the selection. Technique of Order Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision making technique, will be used in this work.

There are insufficient power installations in Nigeria. A number of power plants are being built. In most cases, political considerations are put forward in building some power plants. For instance, the National Integrated Power Projects with ten gas turbine based power stations, some of the power stations are located outside the Niger Delta region where natural gas is in abundant to power the plants. As at today some of those power stations located outside the Niger Delta region are not being operated because of difficulty in assessing natural gas. Power stations should actually be located in different locations but the primary energy source should be considered. This appears not to be the case. In this research therefore, the suitability of siting different power stations in the North-East and the Niger Delta regions of Nigeria will be analyzed using carefully selected criteria.

There are several works on gas turbine performance analysis, some looking at the thermodynamics performance while others equally look at the economics of the operations of gas turbine power plants [6-10]. There are several studies on solar power and other renewable power systems. Abdullahi et al. (2017) [11] discuss the motivational drivers of solar energy development and the barriers hindering the implementation. Saturday & Aderibigbe (2020) [12] considered the

economic implications of using solely wind energy, photovoltaic (PV) or solar systems for electric power generation in Nigeria. Esbond & Funmilayo (2019) [13] examined the energy characteristics of the monthly solar radiation data from Yola, a town in Northeastern Nigeria. Igbinovia (2014) [14] presented an overview of renewable energy potentials in Nigeria.
Emodi & Boo (2015) [15] reviewed the standpoint of efficient energy management with a strategic concentration on the demand side energy savings and Renewable Energy resource potential in Nigeria to ensure sustainable development. Akorede et al. (2016) [16] presented a critical review of the available renewable energy resources such as solar hydropower, biomass and wind energy in Nigeria. The main objective of Ref [17] is to present and analyze the renewable energy potentials in Nigeria with special attention and consideration on solar energy development.

Aside the several studies on gas turbines and renewable energy systems with focus on Nigeria, the issues in the Nigeria power sector have been studied extensively and solutions proffered [2-5, 18-20]. Also, TOPSIS as a multi-criteria decision making tool has been widely applied [21-24]. Its application cuts across almost all fields. The application of TOPSIS to select suitable power plants for different regions in Nigeria is seldom found in the literatures today. That is the focus of the present study.

2. METHODOLOGY

Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) a multi-criteria decision making approach was applied in the selection of power plants suitable for installation in two different regions in this study. To do this the power plants and the criteria for the selection must be identified. First we look at the TOPSIS algorithm.

2.1 The TOPSIS Algorithm

TOPSIS is used for selecting the best alternative among a number of alternatives by using a number of criteria. It is a multi-criteria decision making process. The methodology has a number of steps presented in Figure 1.

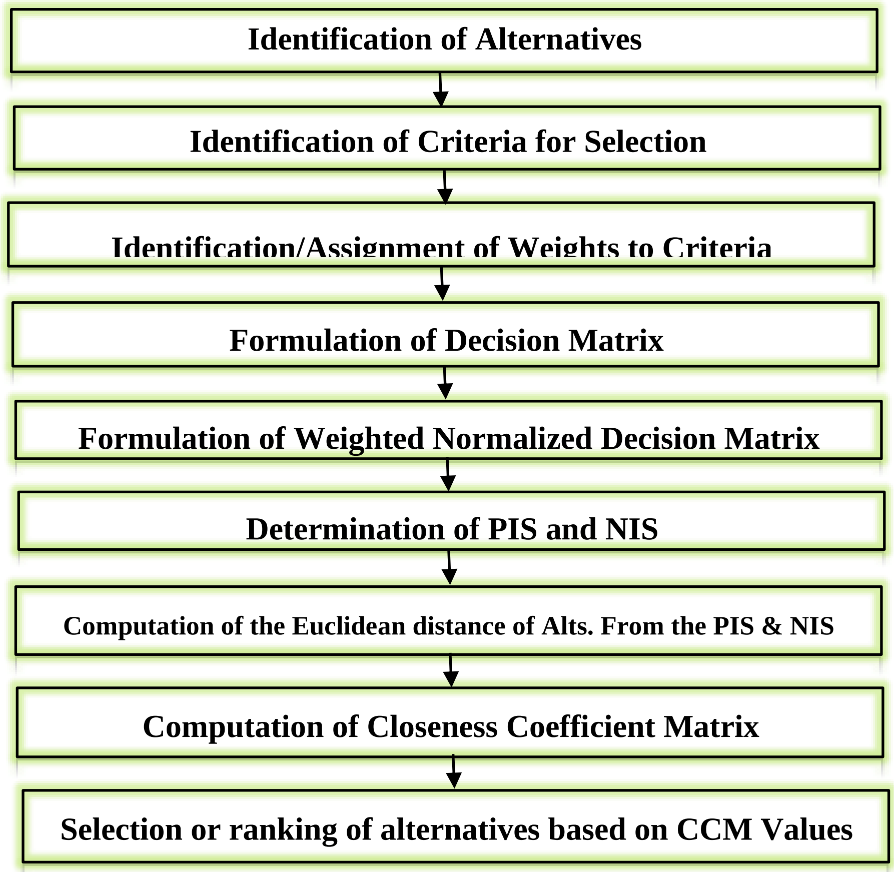

Figure 1: The TOPSIS algorithm

The various steps in the algorithm are considered below and applied to this research

2.1.1 Identification of Alternatives

The options which are available for selection are known as alternatives. In the selection process if only one alternative is to be chosen then the alternatives are termed mutually exclusive. In the present work, we are looking at the suitability of installing different power plants in two geo-political zones of Nigeria. The TOPSIS process leads to the computation of closeness coefficient matrix (CCM) and ranking of the alternatives based on the CCM values. The various alternatives will be ranked based on the CCM values. The alternative with the highest CCM value is the most suitable followed by the next alternative. Selecting only one alternative is not the idea in this work. Thus, the alternatives in this work are not mutually exclusive. Table1 shows the alternatives considered in this work.

Table 1: Alternatives considered in the research

S/No.	Alternative
1	Gas turbine power plant
2	Steam turbine power plant
3	Combined cycle power plant

4	Hydro power plant
5	Wind turbine energy system
6	Solar PV systems

In this work, the energy source of the gas turbine power plant is natural gas while that of the steam turbine power plant is coal.

2.1.2 Identification of Criteria for Selecting the Alternatives

The alternatives are to be selected based on carefully thought out criteria or attributives. The criteria are actually attributes of the alternatives to be selected. The attributes tell the level of importance of the alternatives. For installing a power plant, a number of criteria attributable to power plants must be used. The criteria which were obtained via interactions with experts in the power production industry and the academia are presented in Table 2.

Table 2: Criteria for selecting the power plants

S/No.	Criteria/Attributes
1	Installation cost
2	Operation and maintenance cost
3	Availability of primary energy source
4	Consistency of primary energy source
5	Environmental impact of system operation
6	Package sizes
7	Ease of deployment

2.1.3 Assignment of Weights to the Different Criteria

Each of the criteria is given numerical values between 0 and 1 referred to as weights. The weights tell the level of importance of the different criteria. Each criteria is given one weight thus, the number of weights are equal to the number of criteria used. In this work, we identified seven (7) criteria, hence there are 7 weights given by Equation (1),

$$W = \{w_i : i = 1, 2, \ldots, 7\} \quad (1)$$

where W represents the set of weights and w_i is the weight of the ith criteria. The weights were collected from same experts who provided the criteria needed for selecting the power plants. Different experts give different weights for the different criteria. The average value in each case was used in this work. The attributes may be positive (beneficial) or negative to each alternative Positive attributes were used in this work.

2.1.4 Formulation of Decision Matrix

Each of the alternatives was given a value for each criteria ranging from 1 to 10. For instance, gas turbine power plant has seven attributes, same goes for steam turbine power plant, for the attribute of installation cost, lower installation cost is beneficial. Gas turbine has lower installation cost, hence the value assigned to gas turbine for installation cost will be greater (benefit criteria) than that for the steam turbine power plant. The alternatives are more or less rated with the different criteria. If there are m alternatives, denoted as $A_1, A_2, \ldots, A_n$ and m criteria/attributes denoted as $C_1, C_2, \ldots, C_m$, a decision matrix of order m by n can be formed as shown below:

	A_1	A_2				A_n
C_1	x_{11}	x_{12}	.	.	.	x_{1m}
C_2	x_{21}	x_{22}	.	.	.	x_{2m}
.	.	.	.	.		
.	.	.	.	.	.	
.	.	.	.	.	.	
C_m	x_{n1}	x_{n2}	.	.	.	x_{nm}

The elements of the matrix are denoted as x_{ij}, where i represents the row and j the column. The element d_{ij} represents the rating of the jth alternative (A_j) with respect to the ith criteria (C_i).

The ratings of the alternatives to form the decision matrix were provided by the experts in the power production and the academia. Table 3 shows the appearance of the decision matrix where * represents the different ratings provided by the experts. The average value obtained from the different experts for the rating of each alternative was used in this work. The alternatives are indicated with short forms – GT for gas turbine power plant, ST for steam turbine power plant CC for combined cycle power plant, hydro for hydro power plant, Wind for wind turbine energy generation system and Solar for solar PV system. Appendix B shows the average values of the ratings of the different alternatives obtained from the field.

Table 3: Decision matrix

Criteria	**Rating of alternatives**					
	GT	**ST**	**CC**	**Hydro**	**Wind**	**Solar**
Installation cost	*	*	*	*	*	*
Operation and maintenance cost	*	*	*	*	*	*
Availability of primary energy source	*	*	*	*	*	*
Consistency of primary energy source	*	*	*	*	*	*
Environmental impact of system operation	*	*	*	*	*	*
Package sizes	*	*	*	*	*	*
Ease of deployment	*	*	*	*	*	*

2.1.5 Formulation of Weighted Normalized Decision Matrix

The formulation of the normalized weighted decision matrix can be carried out in two basic steps: viz, normalization of the decision matrix and multiplying the entries in the decision matrix by the different weights of the attributes. Normalization of the entries in the decision matrix entails making the entries comparable. Giving the entries in the decision matrix as d_{ij}, the normalized entries or elements are obtained as in Equation (2),

$$n_{ij} = \frac{x_{ij}}{\left\{\sum_{j=1}^{n}\left(x_{ij}{}^{2}\right)\right\}^{0.5}} \tag{2}$$

where n_{ij} are the normalized entries. The normalization is done row by row, applying each attribute across the various alternatives. The normalized entries are obtained by dividing the entries in each row by the norm of the vector of that row. The next step is to multiply the entries in the normalized decision matrix with the different weights to obtain the normalized weighted decision matrix. This is given by Equation (3),

$$\varphi_{ij} = w_i n_{ij} \tag{3}$$

where φ_{ij} are the entries in the weighted normalized decision matrix.

3.2.6 Determination of Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

Each of the alternatives has a performance value for each attribute/criteria denoted by the entries in the weighted normalized decision matrix. The PIS represents the highest performance of all the alternatives (highest value) for each criterion, selected across each row. It is the highest value in each row of the weighted normalized decision matrix. The NIS on the other hand represents the lowest performance considering all the alternatives (lowest value) for each criterion. It is the lowest value in each row of entries. The number of PIS and NIS values are equal to the number of criteria used. Denoting P^+ as the set of PIS values and N^- as the set of NIS values, they are given by Equations (4) and (5) respectively,

$$P^+ = \varphi_1^+, \varphi_2^+, \dots, \varphi_m^+ = \left(\max_j v_{ij} \middle| i \in B\right) \tag{4}$$

$$N^- = \varphi_1^-, \varphi_2^-, \dots, \varphi_m^- = \left(\min_j v_{ij} \middle| i \in B\right) \tag{5}$$

where $\varphi_1^+, \varphi_2^+, \dots, \varphi_m^+$ are the maximum values of the entries in each column (corresponding to each alternative) while $\varphi_1^-, \varphi_2^-, \dots, \varphi_m^-$ are the respective minimum values, B indicates benefit criteria.

2.1.7 The Euclidean Distance of the Alternatives from the PIS and NIS

The next step in the TOPSIS algorithm is to compute the distance between the entries for each alternative in a given column from both the highest value (PIS) and the lowest value (NIS). Both distances form a set of values equivalent to the number of alternatives. The Euclidean distance between the PIS and the entries of each alternative (denoted as d^+) evaluated down each column of alternatives is given by Equation (6),

$$d^{+} = \left\{\sum_{i=1}^{m}\left(\varphi_i^{+} - \varphi_{ij}\right)^2\right\}^{\frac{1}{2}} \tag{6}$$

The Euclidean distance between the NIS and the entries of each alternative (denoted as d^{-}) evaluated down each column of alternatives is given by Equation (7),

$$d^{-} = \left\{\sum_{i=1}^{m}\left(\varphi_i^{-} - \varphi_{ij}\right)^2\right\}^{\frac{1}{2}} \tag{7}$$

2.1.8 Formulation of Closeness Coefficient Matrix (CCM)

The CCM is a row matrix consisting of number of elements equivalent to the number of alternatives. Each element in the CCM represents the final TOPSIS score for each of the alternatives. The entries in the CCM, computed for column and denoted as C^{φ} is given by Equation (8)

$$C^{\varphi} = \frac{d^{-}}{(d^{-}+d^{+})} \tag{8}$$

If the alternatives are mutually exclusive, the alternative with the highest value of the entries in the CCM will be chosen. In this work, the alternatives will be ranked in order of the magnitude of the CCM entries to see which power plant is more suitable in the different locations considered. Entries in the CCM closer to unity are more suitable; thus, for each of the alternatives, the closer the entry value pertaining to each alternative to unity, the better the alternative.

3 RESULTS AND DISCUSSION

The decision matrix for the Niger Delta region is shown in Table 4 while that for the North-East region is shown in Table 5. The weights of the attributes, applicable to all cases, are shown in Table 6.

Table 4: Decision matrix with alternative ratings for the Niger Delta region

Criteria	Rating of alternatives					
	GT	ST	CC	Hydro	Wind	Solar
Installation cost	9.5	8.8	8.5	6.5	5.5	5.2
Operation and maintenance cost	6.5	7	8	8.5	9	9.5
Availability of primary energy source	9.8	6	9.8	8	6.5	6
Consistency of primary energy source	9.8	9.8	9.8	7.5	6.5	4.5
Environmental impact of system operation	7	4	8.3	8.5	9	8.5
Package sizes	7	6	5.5	5	9	9.5
Ease of deployment	7.5	6	5.5	4	8	9.5

Table 5: Decision matrix with alternative ratings for the North-East region

Criteria	Rating of alternatives					
	GT	ST	CC	Hydro	Wind	Solar
Installation cost	9.5	8.8	8.5	6.5	5.5	5.2
Operation and maintenance cost	6.5	7	8	8.5	9	9.5
Availability of primary energy source	4	4	4	9	7.8	7.5
Consistency of primary energy source	9.2	9.2	9.2	7.5	6.8	5.5
Environmental impact of system operation	7	4	8.3	8.5	9	8.5
Package sizes	7	6	5.5	5	9	9.5
Ease of deployment	7.5	6	5.5	4	8	9.5

Table 6: Criteria and their respective weights

S/No.	Criteria/Attributes	Weights
1	Installation cost	0.95
2	Operation and maintenance cost	0.92
3	Availability of primary energy source	0.95
4	Consistency of primary energy source	0.88
5	Environmental impact of system operation	0.95
6	Package sizes	0.4
7	Ease of deployment	0.45

Out of the seven criteria employed, the weights assigned to package sizes and ease of deployment are much lower. The results obtained at the different steps in the execution of the TOPSIS algorithm are shown in Table 7 to 10 for the Niger Delta region. For the North-East region, the intermediate results are shown in Tables 11 to 14.

Table 7: The normalized decision matrix for the Niger Delta region

Criteria	Alternatives					
	GT	ST	CC	Hydro	Wind	Solar
Installation cost	0.5156	0.4776	0.4613	0.3528	0.2985	0.2822
Operation and maintenance cost	0.3255	0.3505	0.4006	0.4257	0.4507	0.4757
Availability of primary energy source	0.2550	0.2550	0.2550	0.5737	0.4972	0.4781

Consistency of primary energy source	0.4679	0.4679	0.4679	0.3814	0.3458	0.2797
Environmental impact of system operation	0.3692	0.2110	0.4378	0.4484	0.4747	0.4484
Package sizes	0.3966	0.3400	0.3116	0.2833	0.5099	0.5383
Ease of deployment	0.4383	0.3507	0.3215	0.2338	0.4676	0.5552

Table 8: The weighted normalized decision matrix

Criteria	**Alternatives**					
	GT	**ST**	**CC**	**Hydro**	**Wind**	**Solar**
Installation cost	0.4898	0.4537	0.4383	0.3351	0.2836	0.2681
Operation and maintenance cost	0.2995	0.3225	0.3686	0.3916	0.4146	0.4377
Availability of primary energy source	0.4838	0.2962	0.4838	0.3949	0.3209	0.2962
Consistency of primary energy source	0.4275	0.4275	0.4275	0.3272	0.2836	0.1963
Environmental impact of system operation	0.3508	0.2004	0.4159	0.4260	0.4510	0.4260
Package sizes	0.1586	0.1360	0.1247	0.1133	0.2040	0.2153
Ease of deployment	0.1973	0.1578	0.1447	0.1052	0.2104	0.2499

The PIS and the NIS are shown as row matrices below:
PIS = {0.4898, 0.4377, 0.4838, 0.4275, 0.4510, 0.2153, 0.2499}

NIS = {0.2681, 0.2995, 0.2962, 0.1963, 0.2004, 0.1133, 0.1052}

Table 9: The distance of each alternative from the PIS

Criteria	Alternatives					
	GT	**ST**	**CC**	**Hydro**	**Wind**	**Solar**
Installation cost	0.0000	0.0013	0.0027	0.0239	0.0425	0.0492
Operation and maintenance cost	0.0191	0.0133	0.0048	0.0021	0.0005	0.0000
Availability of primary energy source	0.0000	0.0352	0.0000	0.0079	0.0265	0.0352
Consistency of primary energy source	0.0000	0.0000	0.0000	0.0101	0.0207	0.0535
Environmental impact of system operation	0.0100	0.0628	0.0012	0.0006	0.0000	0.0006
Package sizes	0.0032	0.0063	0.0082	0.0104	0.0001	0.0000
Ease of deployment	0.0028	0.0085	0.0111	0.0209	0.0016	0.0000
$\sum_{i=1}^{m}(\varphi_i^+ - \varphi_{ij})^2$	0.0351	0.1273	0.0280	0.0760	0.0920	0.1384
$d^+ = \left\{\sum_{i=1}^{m}(\varphi_i^+ - \varphi_{ij})^2\right\}^{\frac{1}{2}}$	0.1874	0.3568	0.1672	0.2756	0.3033	0.3721

Table 10: The distance of each alternative from the NIS

Criteria	Alternatives					
	GT	ST	CC	Hydro	Wind	Solar
Installation cost	0.0492	0.0345	0.0290	0.0045	0.0002	0.0000
Operation and maintenance cost	0.0000	0.0005	0.0048	0.0085	0.0133	0.0191
Availability of primary energy source	0.0352	0.0000	0.0352	0.0097	0.0006	0.0000
Consistency of primary energy source	0.0535	0.0535	0.0535	0.0171	0.0076	0.0000
Environmental impact of system operation	0.0226	0.0000	0.0464	0.0509	0.0628	0.0509
Package sizes	0.0021	0.0005	0.0001	0.0000	0.0082	0.0104
Ease of deployment	0.0085	0.0028	0.0016	0.0000	0.0111	0.0209
$\sum_{i=1}^{m}\left(\varphi_i^- - \varphi_{ij}\right)^2$	0.1709	0.0917	0.1705	0.0907	0.1038	0.1013
$d^- = \left\{\sum_{i=1}^{m}\left(\varphi_i^- - \varphi_{ij}\right)^2\right\}^{\frac{1}{2}}$	0.4134	0.3029	0.4129	0.3012	0.3222	0.3182

Table 11: The normalized decision matrix for the North-East region

Criteria	Alternatives					
	GT	ST	CC	Hydro	Wind	Solar
Installation cost	0.5156	0.4776	0.4613	0.3528	0.2985	0.2822
Operation and maintenance cost	0.3255	0.3505	0.4006	0.4257	0.4507	0.4757

Availability of primary energy source	0.2550	0.2550	0.2550	0.5737	0.4972	0.4781
Consistency of primary energy source	0.4679	0.4679	0.4679	0.3814	0.3458	0.2797
Environmental impact of system operation	0.3692	0.2110	0.4378	0.4484	0.4747	0.4484
Package sizes	0.3966	0.3400	0.3116	0.2833	0.5099	0.5383
Ease of deployment	0.4383	0.3507	0.3215	0.2338	0.4676	0.5552

Table 12: The weighted normalized decision matrix

Criteria	Alternatives					
	GT	**ST**	**CC**	**Hydro**	**Wind**	**Solar**
Installation cost	0.4898	0.4537	0.4383	0.3351	0.2836	0.2681
Operation and maintenance cost	0.2995	0.3225	0.3686	0.3916	0.4146	0.4377
Availability of primary energy source	0.2422	0.2422	0.2422	0.5450	0.4724	0.4542
Consistency of primary energy source	0.4117	0.4117	0.4117	0.3356	0.3043	0.2461
Environmental impact of system operation	0.3508	0.2004	0.4159	0.4260	0.4510	0.4260
Package sizes	0.1586	0.1360	0.1247	0.1133	0.2040	0.2153
Ease of deployment	0.1973	0.1578	0.1447	0.1052	0.2104	0.2499

The PIS and the NIS are shown as row matrices below:
PIS = {0.4898, 0.4377, 0.5450, 0.4117, 0.4510, 0.2153, 0.2499}
NIS = {0.2681, 0.2995, 0.2422, 0.1963, 0.2004, 0.1133, 0.1052}

Table 13: The distance of each alternative from the PIS for the North-East region

Criteria	Alternatives					
	GT	**ST**	**CC**	**Hydro**	**Wind**	**Solar**
Installation cost	0.0000	0.0013	0.0027	0.0239	0.0425	0.0492
Operation and maintenance cost	0.0191	0.0133	0.0048	0.0021	0.0005	0.0000
Availability of primary energy source	0.0917	0.0917	0.0917	0.0000	0.0053	0.0083
Consistency of primary energy source	0.0000	0.0000	0.0000	0.0058	0.0115	0.0274
Environmental impact of system operation	0.0100	0.0628	0.0012	0.0006	0.0000	0.0006
Package sizes	0.0032	0.0063	0.0082	0.0104	0.0001	0.0000
Ease of deployment	0.0028	0.0085	0.0111	0.0209	0.0016	0.0000
$\sum_{i=1}^{m}\left(\varphi_i^+ - \varphi_{ij}\right)^2$	0.1268	0.1838	0.1196	0.0638	0.0616	0.0855
$d^+ = \left\{\sum_{i=1}^{m}\left(\varphi_i^+ - \varphi_{ij}\right)^2\right\}^{\frac{1}{2}}$	0.3561	0.4287	0.3459	0.2526	0.2481	0.2923

Table 14: The distance of each alternative from the NIS for the North-East region

Criteria	Alternatives					
	GT	**ST**	**CC**	**Hydro**	**Wind**	**Solar**
Installation cost	0.0492	0.0345	0.0290	0.0045	0.0002	0.0000
Operation and maintenance cost	0.0000	0.0005	0.0048	0.0085	0.0133	0.0191

Availability of primary energy source	0.0000	0.0000	0.0000	0.0917	0.0530	0.0449
Consistency of primary energy source	0.0274	0.0274	0.0274	0.0080	0.0034	0.0000
Environmental impact of system operation	0.0226	0.0000	0.0464	0.0509	0.0628	0.0509
Package sizes	0.0021	0.0005	0.0001	0.0000	0.0082	0.0104
Ease of deployment	0.0085	0.0028	0.0016	0.0000	0.0111	0.0209
$\sum_{i=1}^{m}\left(\varphi_i^- - \varphi_{ij}\right)^2$	0.1097	0.0657	0.1093	0.1635	0.1519	0.1462
$d^- = \left\{\sum_{i=1}^{m}\left(\varphi_i^- - \varphi_{ij}\right)^2\right\}^{\frac{1}{2}}$	0.3312	0.2563	0.3305	0.4044	0.3898	0.3824

The closeness coefficient matrices (TOPSIS scores) for the alternatives which represent the performance of each alternative are shown in Figure 1 and Figure 2 for the Niger Delta region and the North-East region respectively.

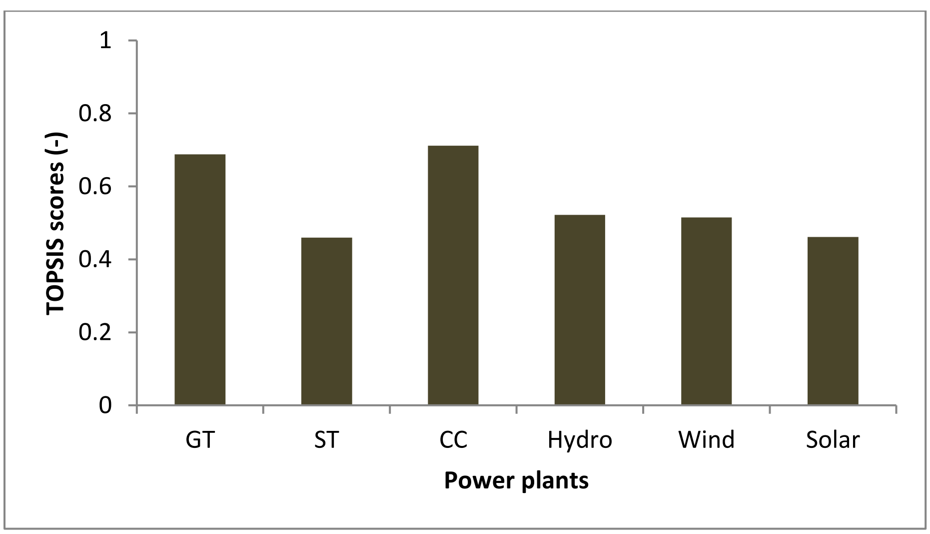

Figure 1: Final TOPSIS scores for the alternatives for the Niger Delta region

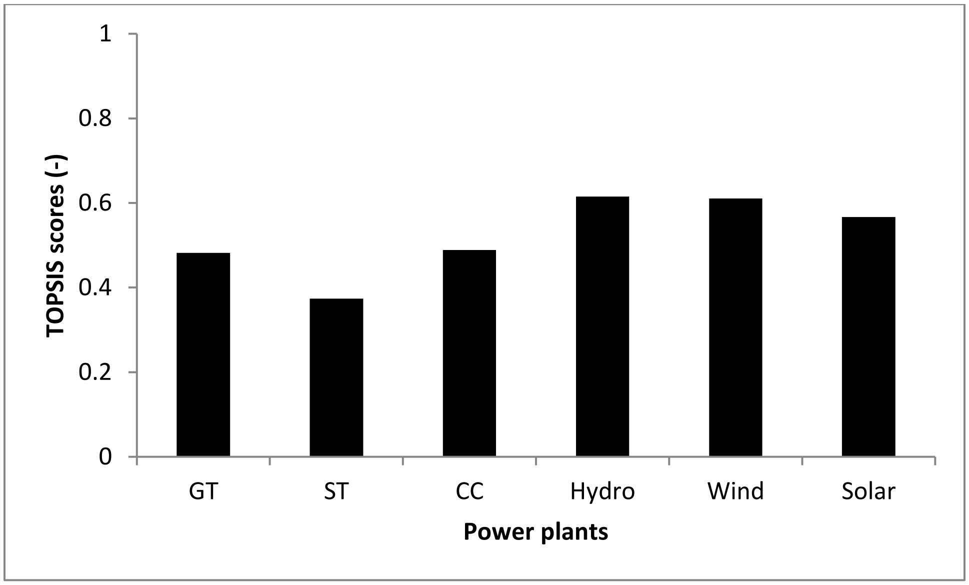

Figure 2: Final TOPSIS scores for the alternatives for the North-East region

From the results of the final TOPSIS scores, the operation of combined cycle power plants is more favourable in the Niger Delta region followed by gas turbine power plant. The order of preference of operation of the other power plants in the Niger Delta region is hydropower plant wind turbine power plant, solar power plant and steam turbine power plant. Steam turbine power plant is the least favourable power plant to be operated in the Niger Delta region going by the 6 criteria used in the TOPSIS analysis. For the North East region the renewable energy systems for power production are more favourable to be operated. Hydropower plant tops the list followed by wind energy system and solar power plants in that order. This is followed by combined cycle power plant, gas turbine power plant and steam turbine power plant.

For both regions, considering the renewable energy power production options, the operation of hydropower plants is the best, followed by wind and solar. Generally, it is more favourable to operate power plants in the Niger Delta region compared to the North-East region. This is deduced from the TOPSIS scores. In the Niger Delta region, the TOPSIS score for the least favourable power plant system is 0.459 while that for the most favourable power plant system is 0.712. In the North-East region, the least favourable power plant has a TOPSIS score of 0.374 while the most favourable power plant to be operated has a TOPSIS score of 0.615.

4. CONCLUSIONS

In applying TOPSIS to the selection of six different power plants in terms of the suitability of installing the power plants in two regions of Nigeria, the following findings were made:

i. Generally, it is more suitable to install power plants in the Niger Delta region of Nigeria compared to the North-East region;
ii. It is more suitable to install combine cycle power plant in the Niger Delta region;

iii. It is more suitable to install the renewable energy based power plants in the North-East region;
iv. For the renewable energy based power plants, it is more suitable to install hydro power followed by wind energy system for both regions;
v. Steam turbine power plant is the least suitable power plant to be installed in both regions.

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