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POWER GENERATION PROBLEMS RANKING USING A COMBINATION OF AHP AND MOORA TECHNIQUES

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Abstract: The inadequate electricity generation in Nigeria is the major reason for her economic woes. From the literature some of the problems affecting power generation in Nigeria are lack of policy continuity, drought, Militant activities and corruption. However the degree of impact each of the problem has on power generation varies. Therefore there a need to develop a tool that will identify critical problems such that power generation managers' will use bulk of the meagre available resources in addressing the more critical ones. In this paper a tool which combines Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) technique with Analytical Hierarchy Process (AHP) is proposed for the prioritization of the problems affecting power generation in Nigeria. The technique is illustrated with a numerical example developed from data from experts. From the result of the analysis, poor maintenance of power generation infrastructure, militant activities and corruption are the most critical problems hampering power infrastructure development in Nigeria. The proposed technique have been proven to be effective in prioritizing power generation challenges as it produces almost completely same result with well-known mathematical techniques in literature.
Keywords: Power generation problems, MOORA method, AHP, decision criteria, power generation infrastructure

1. INTRODUCTION

The key to economic development of developing Countries is having a strong power network that guarantee constant and efficient supply of power to homes and industries. However power supply in developing Countries such as Nigeria is neither constant nor efficient. The inefficient   supply of power by the organisations entrusted with the assignment is the major reason for developing Nations economic woes. For example in Nigeria due to erratic power supply most industries have relocated to other countries with more stable electricity and the remaining ones operating and maintaining infrastructure at high cost and the citizens are made to bear the burden of the cost and invariably citizens' poor standard of living.

Concerted efforts had been made by successive Government in Nigeria with respect to solving power crisis and regrettably none of the effort has yielded positive result with the power generation installed capacity remaining below 25,000 MW whilst the available capacity is below 5,000 MW for an estimated population of about 180,000,000 (Olaoye, 2016). Various reasons have been attributed to the poor power generation and the gap between the installed capacity and the available capacity. Some of the reasons are; poor power infrastructure maintenance, Militant activities, corruption and lack of energy mix. Each of the problem have diverse degree of impact on the level of power generation while some are more critical others are less critical. There is therefore the need to identify those ones that are more critical so that more attention can be given to them in the face of meagre resources available for power infrastructure development in Nigeria.

However, studies carried out on power generation system in Nigeria by most researchers had been mainly on performance assessment, reliability analysis and problems identification. Emovon et al., (2011a) proposed a model for assessment of the performance of Egbin thermal power station, Nigeria. Specifically, the overall model was developed for estimating production losses due to system unavailability. In a similar research Oyedepo et al., (2014) investigated the performance of a gas turbine power plant in Nigeria. Power outage cost resulting from plant downtime was estimated. The study indicated that revenue loss due to system downtime amount to $251 million over the period investigated. Ohajianya et al., (2014) discussed factors responsible for unstable electric power supply in Nigeria. The authors identified factors such as inappropriate power reforms and inept workforce. Olaoye et al., (2016) investigated the causes of power crisis in Nigeria and suggested the need to harness renewable energy in order to ameliorate the energy crisis. In a paper authored by Sambo et al., (2012) factors such as lack of fund and low private sector participation were identified as the bane of energy crisis in Nigeria. The authors suggested that privatisation is the key to resolving power sector challenges.

However only a single author have carried out research on prioritisation of power generation problems in Nigeria. Emovon and Samuel (2017) developed a methodology which combines statistical variance method with VIKOR method for the ranking of power generation problems in Nigeria. The author applied statistical

variance method for weights of criteria evaluation and utilized VIKOR for the ranking of power generation problems. The statistical technique used for weights evaluation is an objective weighting technique which eliminates the involvement of the decision makers in the criteria weighting process. Furthermore, the VIKOR methodology and most other MCDM technique is affected by criteria weightage methodology and normalization approach utilized which impact negatively on the output.

There is therefore the need for a more systematic approach which avoids limitations of the above technique. In this paper a tool which combines MOORA method with AHP is presented for prioritizing power generation problems in Nigeria. The AHP method was chosen for decision criteria weights determination because it combine both objective and subjective weighting methodology such that the opinion of the decision maker can be involved in the decision making process. The MOORA method was chosen in this paper due to its simplicity in implementation. Additionally, the method can hardly be affected by the method used for criteria weights and normalization determination (Karande and Chakraborty, 2012).

The tool will assist power generation managers in Nigeria to concentrate on the more critical challenges with the meagre resources available for power infrastructure development.

2. POWER GENERATION PROBLEMS IN NIGERIA

The low power generation and the gap between the installed capacity and available capacity are caused by so many factors. Some have high negative impact on power generation while others have less impact. From the literature (see Emovon & Samuel, 2007; Emovon, et al., 2011; Sambo, et al., 2012; Oricha & Olarinoye, 2012; Oyedepo, 2012; Ohajianya, et al., 2014) some of the problems responsible for this obnoxious development are lack of energy mix, poor maintenance of power generation systems, corruption and inadequate fund. The different problems or factors are briefly described as follows:

— Poor maintenance (A1): The power infrastructure had been poorly maintained by the bodies' entrusted with it. They react to failure rather than having a well define maintenance plan for power infrastructure and this had led to near collapse of power system.

— Corruption (A2): The meagre resources allocated for power generation infrastructure maintenance and expansion are in most cases mismanage thereby leaving little or nothing for power system development.

— Inadequate funding (A3): The budgetary allocation for power infrastructure maintenance and expansions is grossly inadequate for the ever increasing demand for electric power. The consistence increase in the demand is as a result of the geometric increase in human population.

— Militant activities (A4): Since most of the power plant in Nigeria are gas fired, pipelines that supply gas to the power plant are deliberately vandalised by militant in the Niger Delta region of the country in response to failure of successive Government with respect to providing basic amenities in the region. The effect is that gas fired plants are shut down until gas supply are restored.

— Inadequate or lack of manpower (A5): The technical manpower required for optimal maintenance, operation and expansion of power infrastructure are either grossly inadequate or lacking. As a result, the infrastructure are at the mercy of workforce with little or no ideal of optimising power system for maximum performance.

— Wrong location (A6): Due to nepotism and ethnicity most power station are located far from sources of energy and human capacity. This result to extra cost in transporting materials and human resources to power system sites.

— Drought (A7): Low rainfall in some seasons have negative impact on the hydropower system production output.

— Poor electricity pricing (A8): Most consumers of electricity do not have the financial capacity to pay for the actual cost and thereby forcing Government to subsidise the price which invariably deplete resources for power infrastructure development.

— Lack of policy continuity (A9): Most successive Government rather than build on good policies of previous administration, they jettison it and come up with new policies that will eventually be discarded by another Government.

3. DECISION CRITERIA

In prioritising different power generation problems in order to identify the critical ones, decision criteria are needed. For this research the different problems will be ranked based on three decision

Table 1: Decision criteria (Emovon and Samuel, 2017)

S/N	Decision criteria	Description
1	Environmental pollution (E)	The power problem that will result to greater environmental pollution is the most critical.
2	Critical asset damage (C)	The Power problem that will cause more damages to power infrastructure is the most critical
3	Power generation output (P)	The power problem that will result to lower power generation is the most critical

criteria; environmental pollution (E), critical assets damage (C) and power generation output (P). The decision criteria are briefly discussed in Table 1.

4. METHODOLOGY

⊞ Analytical Hierarchy Process (AHP)

AHP is a Multi-Criteria Decision Making tool for resolving decision problem involving multiple criteria. The principle basically involves structuring the complex decision problem in a hierarchical form and reducing the problem to a series of pairwise comparisons matrix and then synthesizing the results to obtain different criteria weights (Emovon, 2016). The AHP was chosen for decision criteria weights evaluation because of its ability to use both qualitative and quantitative data in determining decision criteria weights. Furthermore, it has been applied by some authors in the determination of weights of criteria for different multi-criteria decision problems. Dagdeviren (2009) used the technique to determine weights of criteria in a weapon selection problem. Emovon et al, (2016) applied the AHP method for criteria weights determination in a maintenance interval determination problem for marine systems. The AHP steps are as follows (Caputo et al 2013):

(1) Formation of an **n** x **n** pairwise comparison matrix **G** using pairwise comparison judgment obtained from expert:

$$G = \left[g_{ij}\right]_{nxn} = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ g_{n1} & g_{n2} & \cdots & g_{nn} \end{bmatrix} \qquad (1)$$

where $g_{ij} > 0, g_{ij} = 1/g_{ji}, \quad g_{ii} = 1$

The relative importance of criterion i over that of criterion j is denoted by g_{ij}. For example if criteria i and j are of equal importance $g_{ij} = g_{ji} = 1$. The Saaty AHP scale use by expert in rating of decision criteria is presented in Table 2.

(2) Each criterion weight are then estimated as follows:

Table 2: AHP importance scale (Saaty, 1980)

Score	Relative importance
1	criteria **i** and **j** are of equal importance
3	criterion **i** is slightly more important than criterion **j**
5	criterion **i** is significantly more important than criterion **j**
7	criterion **i** is strongly more important than criterion **j**
9	criterion **i** is extremely more important than criterion **j**
Note: 2, 4, 6 and 8 are intermediate values	

$$w_i = \frac{1}{n}\sum_j \frac{g_{ij}}{\Sigma_i\, g_{ij}} \qquad (2)$$

where w_i is the weight of criteria.

(3) The consistency ratio I_r, is use to ascertain consistency of expert judgment. The value must be less than or equal to 0.1 for comparison judgment obtained from expert to be acceptable. The consistency ratio is estimated as:

$$I_r, = \frac{FI}{RI} \qquad (3)$$

where RI is the equivalent average random value of **FI** for an **n** x **n** matrix, and the values are shown in Table 3, while **FI** is the consistency index and can be calculated as

$$FI = \frac{\lambda_{max} - n}{n - 1} \qquad (4)$$

where λ_{max} is the maximum eigenvalue

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \qquad (5)$$

⊞ MOORA method

MOORA an acronym for Multi-Objective Optimisation on the basis of Ratio Analysis was developed by Brauers & Zavadskas (2006). The

Table 3: RI values for different matrix order (Saaty, 1980)

n	1	2	3	4	5	6	7
RI	0	0	0.52	0.89	1.11	1.25	1.35

technique has been applied in solving different multi-criteria decision problems. Chakraborty (2011) applied the MOORA technique in real life manufacturing multi-criteria decision problems. Karande & Chakraborty (2012) used the technique in addressing material selection decision problem. Gorener et al (2016) utilized the approach to select optimal bank location site. The method was chosen in this paper because it is easy to understand and implement. Furthermore, it is barely affected by decision criteria weighting techniques nor the normalisation techniques applied unlike most other methods (Karande & Chakraborty, 2012).

The steps applicable to the MOORA method are as follows (Yazdani et al, 2016):

(1) Formation of the decision matrix. The decision matrix is formed as follows:

$$Z = (z_{ij})_{m.n} \tag{6}$$

(2) The decision matrix normalisation: The normalisation of the decision matrix is as follows:

$$y_{ij} = \frac{z_{ij}}{\sqrt{\sum_{i=1}^{m} z_{ij}^2}}, \qquad i = 1,2,\dots,m; \quad j = 1,2,\dots,n \tag{7}$$

where y_{ij} is the normalised matrix.

(3) Evaluation of the weighted normalised matrix is as follows:

$$v_{ij} = y_{ij}.w_j \tag{8}$$

(4) Evaluate benefit and cost criteria overall rating for each alternatives as follows.

$$Q_i^+ = \sum_{j \in J^{Max}} v_{ij} \tag{9}$$

$$Q_i^- = \sum_{j \in J^{Min}} v_{ij} \tag{10}$$

where J^{Max} denote index for benefit criteria while J^{Min} denote index for cost criteria. For the benefits and cost criteria the higher and the lower values are desirable respectively.

(5) Determine alternatives overall performance index. The overall performance index for each alternatives is evaluated as follows:

$$Q_i = Q_i^+ - Q_i^- \tag{11}$$

Based on the performance index, Q_i, the alternatives are ranked. The higher the value of the index the better the alternative.

5. RESULTS AND DISCUSSION

As a result of non-availability of quantitative data, qualitative approach was applied. The qualitative information utilised in this paper was obtained from the work of Emovon and Samuel 2017. The information was adapted in order to have unbiased comparison with methodology utilised by the authors. In the authors paper two expert assigned rating to each of the power problem with respect to three decision criteria using 5-point likert scale. The two experts rating were averaged to formed a decision Table (matrix) shown in Table 4.

Since decision criteria weights determination is required in the MOORA technique analysis, weights of criteria were evaluated using AHP technique. Applying Equation 1 to pairwise comparison judgment generated from expert, the AHP decision matrix is formed and is shown in Table 5.

Next Equation 2 is applied to the decision matrix in Table 5 to estimate the weights of decision criteria and the values of 0.2599, 0.3275 and 0.4126 were obtained for E, C and P respectively. A consistency ratio was evaluated using Equation 3-5 and a ratio of 0.056 was obtained indicating that the expert comparison judgment is acceptable.

Having obtained weights of decision criteria, the next step is to rank the power generation problems with the MOORA method. Applying the MOORA method, the decision matrix in Table 4 is normalised using Equation 7 and the normalised decision matrix is show in Table 6. Then the weighted normalised matrix is calculated by applying Equation 8 and results presented in Table 7. This is followed with the evaluation of benefit (maximum) and cost criteria (minimum) using Equations 9 and 10 and the results obtained are shown in Table 8. In this paper all the criteria are taken as benefit because of the way the questionnaire were designed and the nature of the decision problem. Hence all the cost criteria values are zeroes. Thereby reducing the MOORA technique to Weighted Sum Method (WSM). The overall performance index is evaluated by applying Equation 11 and the results are also presented in Table 8 and Figure 1.

Table 4: MOORA technique decision matrix

Power generation problems	E	C	P
A1	2.5	5	5
A2	2	3	5
A3	2.5	3.5	4
A4	4	3.5	4
A5	3	3	3
A6	3	2	3
A7	1	1	2
A8	2	2.5	1.5
A9	1.5	3	3

Table 5: AHP decision matrix

	E	C	P
E	1	1	2
C	1	1	1
P	0.5	1	1

Table 6: Normalised decision matrix

Power generation problems	E	C	P
A1	0.0855	0.1748	0.1922
A2	0.0684	0.1049	0.1922
A3	0.0855	0.1224	0.1537
A4	0.1368	0.1224	0.1537
A5	0.1026	0.1049	0.1153
A6	0.1026	0.0699	0.1153
A7	0.0342	0.0350	0.0769
A8	0.0684	0.0874	0.0577
A9	0.0513	0.1049	0.1153

Table 7: Weighted normalised decision matrix

Power generation problems	E	C	P
A1	0.0855	0.1748	0.1922
A2	0.0684	0.1049	0.1922
A3	0.0855	0.1224	0.1537
A4	0.1368	0.1224	0.1537
A5	0.1026	0.1049	0.1153
A6	0.1026	0.0699	0.1153
A7	0.0342	0.0350	0.0769
A8	0.0684	0.0874	0.0577
A9	0.0513	0.1049	0.1153

Table 8: MOORA performance index and Rank

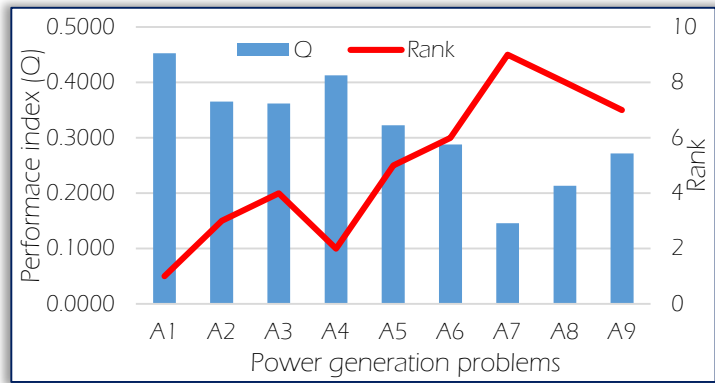| Power generation problems	Q^+	Q^-	Q	Rank
A1	0.4525	0	0.4525	1
A2	0.3655	0	0.3655	3
A3	0.3616	0	0.3616	4
A4	0.4129	0	0.4129	2
A5	0.3228	0	0.3228	5
A6	0.2878	0	0.2878	6
A7	0.1460	0	0.1460	9
A8	0.2135	0	0.2135	8
A9	0.2715	0	0.2715	7

Figure 1: MOORA performance index and Rank

From Table 8 and Figure 1, the three most critical power generation problems are A1, A4 and A2 having rank first, second and third position respectively while the least critical one is A7 having rank ninth position among the nine alternatives. On the basis of this result, there is the need for the Nigeria Government to channel bulk of it power budgetary allocation in addressing these three most critical power challenges in order to overcome her energy crisis. However the result of the analysis may be influenced by factors such as experts' opinion, decision criteria, decision criteria weights and normalisation procedure. When one or more of this factors are modified to suit specific need of the power generation managers/decision makers, the ranking of the alternatives (power generation problems) may change. Nevertheless, the three power generation problems rank as the most critical in this paper had always appeared in almost all articles in literature as main or part of the reasons for energy crisis in Nigeria thereby affirming the validity of the developed technique. To further validate the proposed ranking technique, we compared it with Vlsekriterijumska Optimizacija Ikompromisno Resenje, meaning; Multicriteria Optimization and Compromise Solution (VIKOR), a mathematical technique Emovon and Samuel (2017) previously utilised in solving the same problem and with another mathematical ranking tool refer to as Multi-Attribute Utility Theory (MAUT). The AHP proposed as weighting technique in this paper was applied in evaluating criteria weights for the VIKOR and MAUT techniques as opposed to the statistical variance method applied by Emovon and Samuel (2017) for unbiased comparison.
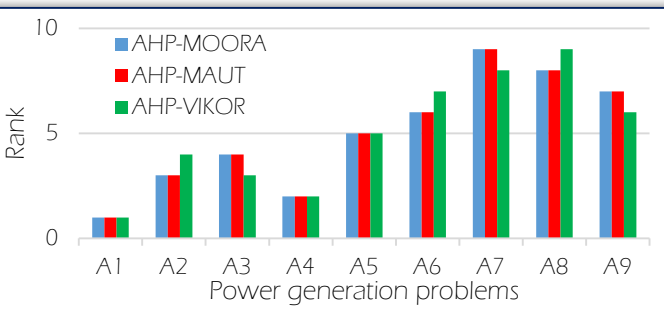

Figure 2: AHP-MOORA method in comparison with other mathematical techniques

Table 9: AHP-MOORA method in comparison with other mathematical techniques

Power generation problems	Performance index			Ranking		
	AHP-MOORA	AHP-MAUT	AHP-VIKOR	AHP-MOORA	AHP-MAUT	AHP-VIKOR
A1	0.4525	0.8701	0.0124	1	1	1
A2	0.3655	0.6630	0.2147	3	3	4
A3	0.3616	0.6294	0.1608	4	4	3
A4	0.4129	0.7593	0.0682	2	2	2
A5	0.3228	0.5138	0.4145	5	5	5
A6	0.2878	0.4320	0.4819	6	6	7
A7	0.1460	0.0589	0.8984	9	9	8
A8	0.2135	0.2094	0.9072	8	8	9
A9	0.2715	0.3839	0.4946	7	7	6

The performance index obtained for each methods from the comparative analysis are presented in Table 9. The ranking of the power generation problems based on these performance indexes are presented in Table 9 and Figure 2. From Table 9 and Figure 2, the AHP-MOORA and the AHP-MAUT methods produces the same ranking of the power generation problems and produces almost the same ranking with the AHP-VIKOR methods. This has further validated the proposed technique; AHP-MOORA.

5. CONCLUSIONS

This paper presents a technique for ranking power generation problems in Nigeria in order for her to effectively allocate available meagre resource in addressing power challenges. The tool combine MOORA and AHP techniques. While AHP was applied in estimating weights of decision criteria, the MOORA method was used to rank the power generation problems. The MOORA technique was chosen for the ranking of alternatives because it is more stable than most other mathematical techniques. Furthermore, the tool is simple to understand and implement. The following conclusion can be drawn from the study.

— The three most critical power generation problems in Nigeria are Poor maintenance (A1), Militant activities (A4) and Corruption (A2).

— The proposed technique although simpler in terms of implementation produces almost same ranking with other mathematical techniques in literature.

— The MOORA technique is reduced to Weighted Sum Method (WSM) in the absence of cost criteria.

The proposed approach although design for Nigeria scenario, can also be utilised in addressing power generation problems prioritisation decision making in other Nations with similar power generation crisis.

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