A New Decision Making Approach for Generation Capacity Bidding with Economic and Environmental Impacts

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Abstract

Due to frequent change in power demand at each hour, it becomes an important and highly complex to bid generation capacity of independent private power producers. This paper has proposed a new hybrid model consisting of three stages to support the planning body of the utility in the selection of bids with economic and environmental impacts. In the first stage, analytic hierarchy process (AHP) has been used to convert available linguistic qualitative information into quantitative information and award scores to different bids. Second stage decides the validity of the different bidding options and then award scores using unit commitment and optimal power flow algorithms. Finally in the third stage, hurwitz criteria for decision making has been used to determine the composite priority ordering of the bids based on the results obtained from both the first and second stages. This composite priority ordering of the bids makes the planning body efficient, reliable, easy and transparent in selection of the bids.

Introduction

Electrical energy is one of the most versatile forms of energy and it controls the economic growth of the nation. With time, demand of electrical energy is increasing with industrial growth inspaite of adequate generation of electrical energy. For example, in India, in the first five year plan in 1951, the total generation of electrical power was 1712 MW and at the end of 1996 the total generation of power was 83,288 MW. The increase in power generation becomes 49 times in 45 years is an important issue by all standards and therefore generation, supply, demand and management of energy in adequate form became important. Despite of the improvement in generation of electrical energy by the utility is not enough to meet the increase in demand and hence the utilities and Govt. parallel decides to offer and encourage private and foreign investors to invest, build and operate the power projects independently. The utility purchase powers from the private producers are compelled to follow certain Govt. rules and they have to undergo competitive marketplace. A competitive electric marketplace envisages competition in both investment and supply. Competition in supply, on the other hand, is concerned with how owners of existing plant prices their commodities so as to be commercially successful in the contemporary supply-demand marketplace. The traditional planning approach considers several attribute mainly quantitative attributes which effecting the generation and transmission and distribution systems. But in actual practice quantitative and qualitative attributes both effects the cost, efficiency, transparency, regularity etc.

The basic function of an electric power system is to provide adequate supply of electric energy to its customers as economically as possible within a reasonable level of quality and continuity. In this regard, the planning bodies in the utility encourage the private bodies and permit them to generate power based on bidding. The method of priority ordering in the process of selection of bids should be on line, efficient, economical, reliable, flexible, and also transparent. A transparent process would provide maximum information and minimum specifications on a pre-bid basis. The information would enable the bidders to self- score the merits of their projects and they will be able to optimize their bids to enhance customer benefits and the profitability of their projects.

Bidding and Its Evaluation

To implement competitive bidding successfully, evaluation methods must be developed to account for the various factors affecting the desirability of a particular project. In this regard private bidders offer their projects, to be evaluated by the utility. In the existing traditional process of bids evaluation, price factors and non-price factors both have been considered, based on linear self- scoring evaluation systems. In the linear self scoring bid evaluation systems, all these bidding process are base on point systems. A bidder will score points by providing attributes and features deemed desirable by the utility. Bidder with the highest points scored will win the bid. The planning body in the utility is confronted with large volume of information, which need to be analyzed to select the winning bids. The planning body is often left with the traditional planning tools which do not quite meet the requirements because they do not aid the planner to perform the following in an integrated environment.

- effect of unit commitment optimal power flow and wheeling in the bidding process .
- effect of uncertainties associated with various factors like fuel cost, load etc.
- rank the bids based on their overall performance

The bid evaluation process emulates the actual system operation closely to produce realistic estimate of the priority ordering of the bids. In bidding process of self -scoring system where the bidders get to know the attributes (both qualitative and quantitative) deemed desirable by the utility on a pre-bid basis. The main drawback of the self-scoring system is that the award procedure for points is based on experience and engineering judgement of the utility planners rather than a direct analysis of the cost and benefits attributes to the resources. Actually self-scoring system is a project -by project analysis using traditional tools. Hence it has been proposed to develop a multiobjective mathematical model which is expected to perform better than existing approach's due to the individual projects cannot be evaluated in isolation ignoring the mutual interaction with other bidders and utility owned projects. In the proposed model an attempt has been made to develop a multi-criteria decision-making framework such that the above said difficulties can be handled successfully.

The Analytic Hierarchy Process (AHP)

AHP is a technique developed by Thomas L. Saaty to compute weightage and the scoring vector of the particular criteria relative to the importance of the other criterion for a particular bid. The need for AHP to evaluate bids due to the significance of the qualitative aspects which might be equally important with the quantitative features like cost and power transfer capability etc.

The input to the model is qualitative in nature on pair-wise comparisons of relative importance of the criterions based on the expert's judgements. In the proposed method AHP has been used for assigning scoring vector to different criterions. The utility may specify a scoring system for the qualitative parameters for environmental impact, company reputation etc. The step by step algorithm of AHP is described briefly as follows.

Step 1: Identify the important qualitative criteria to be used in the evaluation of bids.
Step 2: Prepare a questionnaire according to the criteria and request the decision-makers to compare the criteria pair-wise.
Step 3: Transform the verbal values into the numerical intensity values using Saaty's intensity Table.
Step 4: Prepare a pair-wise comparison matrix $A=[A_{ij}]$ (rows and columns for each criterion).
Step 5: Calculate the eigen-vector or weight vector of matrix A for different criteria corresponding to the largest eigen-value (L_{max}). Normalize this eigen-vector to get the weight vector for the criteria '**i**'.

Step 6: Calculate the consistency ratio (CR) of matrix A_{ij} using the following equation. $CR=[((L_{max}-n)/(n-1)]/RI$, where RI is the random index. If CR <0.1;then the judgements are consistent and can be accepted. Otherwise repeat from step 2 to step 6;

Step 7: Carry out steps 2-6 for the judgements provided by all the decision makers, and take an arithmetic average of weight vectors to get the weight vector of the criteria.

Step 8: For each criteria define different grades of bids linguistically(Good-G, Normal-N, Bad-B). By using step 1 to step 7 compute the weight of these grades V_g.

Step 9: Final weight is given by;

$$W_{ij} = C_i * V_g.$$

Where, C_i = weight vector for criteria

Step 10: The final AHP score of a bid is then computed as the sum of all the weights corresponding to different linguistic levels.

Hurwitz Criteria

When there exist a trade-off among several planning objectives, it is often impossible to arrive in a certain solution that contains all the optimal values simultaneously. Hurwitz criteria for decision-making has been used to obtain the composite priority ordering among all the bids. It assigns the normalized quantitative values for different criteria such as AHP score, generation cost, unit status and emission co-efficient. The step by step algorithm for Hurwitz criteria is as follows:

Step 1: Identify all the comparative quantitative information's.

Step 2: Normalize all the quantitative information's within 0 and 1.

Step 3: Find the maximum and minimum value of all criteria for each option.

Step 4: Find the weight vector of the ith option using the following equation:

$$H_{vi} = \alpha H_i \ \ + (1-\alpha) L_i ;$$

where,

α=Constant (co-efficient) varies between 0.1 to 0.9;

H_{vi} =weight vector of the i^{th} bid;

H_i = higher value of all the criteria's corresponding to i^{th} bids;

L_i = lower value of all the criteria's corresponding to i^{th} bids;

Step 5: Based on the weight vectors priority ordering of different options can be determined.

Proposed Model

Main objective of this paper is to develop a model which is capable of incorporating linguistic information for bidding criteria including operational and environmental constraints. The step by step algorithm of the proposed hybrid model is explained as follows:

Step 1: Identify the important qualitative criteria to be considered in the evaluation of bids.

Step 2: Prepare a questionnaire and request the decision-makers or experts to compare the criteria's for a given criteria using Table 1.

Table1 1 Expert Opinion for Criteria I Vs Other Criteria's

Criteria	A	B	C	D	E	F	G	H	I
I	*								
II		*							
III			*						
IV					*				
V								*	

*Note: * is provided by the expert.*

A: Equal
B: In between equal and moderate importance
C: Moderate importance
D: In between Moderate importance and essential strong
E: Essential or strong
F: In between Strong and very strong
G: Very strong
H: In between very strong and extreme
I: Extreme

Step 3: Transform the verbal values into the numerical intensity for different opinion using saaty's intensity Table. 2.

Table 2: Saaty's Intensity Table

Verbal scale	Numerical scale
Equal	1
Moderate importance	3
Essential or strong	5
Very strong	7
Extreme	9
Intermediate values	2, 4, 6, 8

Step 4: Prepare a pair-wise comparison matrix $A=[A_{ij}]$, with a row and column for each criterion using Saaty's table and results have been presented in the Table 3.

Table 3: Pair-Wise Comparison Matrix

Criteria	I	II	III	IV	V
I	1	2	3	5	8
II	1 /2	1	2	3	4
III	1 /3	1 /2	1	5	2
IV	1 /5	1 /3	1 /5	1	3
V	1 /8	1 /4	1 /2	1 /3	1

Step 5: Calculate the eigen vectors corresponding to the largest eigen-value (L_{max}) and normalize this eigen-vector to get the weight vector for the criteria **'i.'**

Step 6: Calculate the consistency ratio (CR) of matrix an as
$CR=[((L_{max}-n)/(n-1)]/RI$,

Where,

RI is the random index is assumed 0.9

n = order of the matrix or No. of bids to be score

If CR <0.1; then judgements are consistent and can be accepted. Otherwise repeat from step 2 to 6.

Step 7: Carry out steps 2-6 for the judgements provided by all the decision makers, and take an arithmetic average of weight vectors to get the weight of the criteria i.

Step 8: For each criteria define different grades of bids such as Good, Normal, and Bad etc. By using step from 1 to step 7 compute the weight of these grades V_g.

Step 9: Final weight $W_{i,j} = C_i * V_g$.

Where, C_i = weight vector for criteria

Step 10: The final AHP score of a bid is then computed as the sum of the corresponding Wig values based on the criteria's fixed by the system operator or the utility. For bid No.1 if the utility want to fix the criteria I, II, III, IV and V as good, bad, bad, normal and good respectively then the AHP score will be calculated using the following formula.

$$W_{bid} = W_{I,good} + W_{II,bad} + W_{III,bad} + W_{IV,normal} + W_{V,good} = 1.001640$$

Similarly the AHP scores of the other bids can be calculated and the results have been presented in the Table. 4

Table 4: AHP Score of the Bids

Bids No.	I	II	III	IV	V	AHP
1	good	bad	bad	normal	good	1.001640
2	bad	good	normal	bad	bad	0.714079
3	good	bad	good	normal	bad	1.166358
4	good	good	normal	bad	bad	1.320928
5	normal	bad	bad	good	normal	0.571200
6	normal	normal	bad	bad	good	0.601541
7	good	good	bad	bad	normal	1.285869
8	good	bad	bad	bad	normal	0.924581
9	good	normal	normal	good	bad	1.186355
10	good	bad	bad	bad	normal	0.924581

Step 11: Run the unit commitment and optimal power flow algorithm's including units interested to participate in bidding process and finally assign the weight's.

Step 12: Assign the weights for generation cost associated to each and every bidder.

Step 13: Identify all the quantitative variables. Such as AHP scores, unit status, generation cost of the units and emission (SO_2) co-efficient. The quantitative values used in the proposed model after normalization is shown in Table 5.

Table 5: Normalized values of Step 13

No. Bids	AHP Score	Unit Status	Generation cost (p.u.)	SO_2 coefficient
1	0.758286	1.0000	0.150079	1.0000
2	0.540590	1.0000	0.161069	0.989583
3	0.882985	0.3750	0.075979	0.708333
4	1.00000	1.0000	0.102436	0.854167
5	0.432424	0.2500	0.053853	0.604167

6	0.455397	0.7500	0.081719	0.979167
7	0.973453	0.3750	0.033272	0.739583
8	0.699949	0.7500	1.00000	0.81250
9	0.898124	0.1250	0.154433	0.7500
10	0.699949	0.7500	0.168552	0.5000

Step 14. Our main aim is to maximize the unit status & AHP score and minimize generation cost & SO_2 emission co-efficient. Based on fuzzy set theory Table 6 is modified and approximated to different values within 0 and 1. The final results are presented in the Table 6. and 7.

Table 6 Modified Weight's of Step 14

No. Bids Table	AHP Score	Total time(hour)	Generation cost (RS)	SO_2 coefficient
1	0.758286	1.0000	0.849921	0.0000
2	0.540590	1.0000	0.838931	0.010417
3	0.882985	0.3750	0.924021	0.291667
4	1.00000	1.0000	0.897564	0.145833
5	0.432424	0.2500	0.946147	0.395833
6	0.455397	0.7500	0.918281	0.020833
7	0.973453	0.3750	0.966728	0.260417
8	0.699949	0.7500	0.00000	0.18750
9	0.898124	0.1250	0.845567	0.2500
10	0.699949	0.7500	0.831448	0.5000

Table 7 Approximated Values of step 14

No. Bids	AHP Score	Total time(hour)	Generation cost (RS)	SO_2 co-efficient
1	0.6000	1.0000	0.5000	0.1000
2	0.3000	0.9000	0.3000	0.2000
3	0.7000	0.4000	0.8000	0.8000
4	1.0000	0.8000	0.6000	0.4000
5	0.1000	0.2000	0.9000	0.9000
6	0.2000	0.7000	0.7000	0.3000
7	0.9000	0.3000	1.0000	0.7000
8	0.5000	0.6000	0.1000	0.5000
9	0.8000	0.1000	0.4000	0.6000
10	0.4000	0.5000	0.2000	1.0000

Step 15: Using hurwitz criteria the overall priority weight of the ith bus can has been calculated using the equations:

$$H_{vi} = \mu H_i + (1-\alpha)L_i$$

Step 16: Arrange bid values in the decreasing order. And finally the bids with higher weigh has been selected.

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Bid          Weightage

4            0.700000
7            0.650000
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3	0.600000
10	0.600000
1	0.550000
2	0.550000
5	0.500000
9	0.450000
8	0.450000

Final selection of Bids in descending order is 4 7 3 10 1 2 5 9 6 8

Conclusion

The planning body in an utility is confronted with a large volume of information for generation capacity bidding, due to which existing classical techniques for bidding may face difficulties to handle the imprecisely defined data. In this paper, three-stage hybrid model including information's under fuzzy environment has been developed. It makes easy to handle the imprecisely defined data and aid the planning body in the utility for evaluation of bidding score and select the bid based on their desirability. This methodology impact on new resources, with transparent and economical bidding system in complex electric marketplace. This model accounts for both qualitative and quantitative features of bids using analytic hierarchy process (AHP), unit commitment & optimal power flow algorithms and Hurwitz criteria for decision-making all together makes the bid evaluation process efficient.

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