Optimization of Renewable Energy Big Data Transactions Based on Vector Evaluated Genetic Algorithm

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***Abstract*—To maximize the profits of both buyer and seller in renewable energy big data (REBD) transactions, a vector evaluated genetic algorithm (VEGA) based optimal trading strategy is proposed in this paper. Firstly, the REBD evaluation model is designed to calculate the objective function of VEGA. Multiple dimensions of REBD are used to set up the evaluation model. To address the problem in weight assignment of different aspects, analytic hierarchy process (AHP) based fuzzy evaluation method is adopted. Then, the problem of accessing win-win REBD transactions is converted into a multi-objective optimization problem. On this basis, vector evaluated genetic algorithm (VEGA) was used to solve the transaction optimization problem and find the Pareto solution by searching the non-inferior solution of all proposals. Finally, the accuracy of the proposed algorithm is verified by simulation results of a REBD transaction case.**

***Index Terms*—Analytic hierarchy process, data evaluation, renewable energy big data transaction, vector evaluated genetic algorithm**

I. Introduction

In renewable energy big data (REBD) transaction, buyer and seller usually determine the transaction strategy through negotiation. The gains of the two sides in REBD transaction change with the adjustments of price and the datasets in each negotiation. If the two sides carry out REBD transaction efficiently, the value of REBD can be released opportunely [1].

However, the data evaluation strategies of buyers and sellers are different [2]. From beginning to end, REBD transaction is affected by several factors, for example, the quality of data, the price of data et al. [3-4]. It is challenging to balance the gains of both sides and achieve a win-win solution. Researchers have developed a series of rules to deal with the asymmetry between the gains of the two sides [5-6]. Rarely do researchers build a constructed and flexible evaluation mechanism. As a result, the earning of two participating parties cannot be evaluated scientifically and effectively.

The object of this paper is to introduce a vector evaluated genetic algorithm (VEGA) based optimal trading strategy for REBD transaction. Considering there are various factors related to the value of REBG [7], an analytic hierarchy process (AHP) based REBD evaluation model is established and used to generate the objective function of multi-objective optimization problem. On this basis, VEGA algorithm is used to search the Pareto result of optimization problem. By solving this problem, the optimal price and dataset involved in the transaction can be determined.

II. Evaluation System of Renewable Energy Big Data

The evaluation of REBD is an essential part of bilateral big data transactions. The AHP developed by Thomas L.Saaty in 1970s, is a robust and quantized way to handle complex evaluation problems [8-9]. The AHP is used here to provide a flexible and easily understood way to evaluate REBD. In this section, we formulate the influencing factors of REBD value in a hierarchical structure, which is the first step and probably the most important step of AHP [10].

To provide a convincing evaluation model for data transaction, the factors in evaluation model should include multi-factors [11-13]. The hierarchy should be constructed and the factors at the same layer must be capable of being related to some or all factors in the next higher layer [10]. Focusing on the benefits that the data could bring, 6 factors are taken in the REBD quality evaluation. Accordingly, a four-layer AHP model is built to evaluate the value of REBG in a specific transaction.

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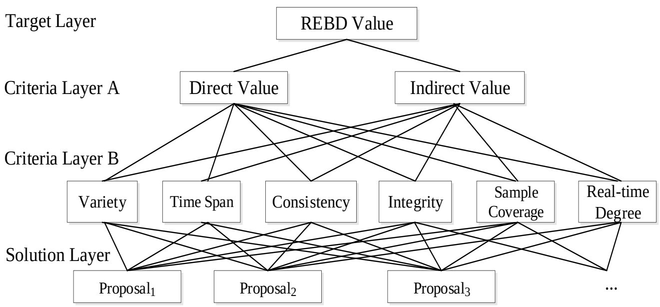

Fig. 1. AHP model of renewable energy big data valuation

The established system consists of a target layer, two criteria layers and a solution layer. The solution layer includes all possible transaction proposals based on an arbitrarily part of REBD that sellers can provide. Buyers and sellers can change the properties of trading object by adjust transaction proposal within an acceptable range.

The criteria layer B is used to evaluate the value of REBD in six dimensions: variety, time span, consistency, integrity, sample coverage and real-time degree. The criteria layer A represents the direct and indirect value of REBD in the transaction proposal, which can be calculated by aggregating the scores of the factors in criterion layer B according to their relative weights. The relative weights of the 6 factors in criterion layer B with respect to the elements in criterion layer A are obtained by constructing judgment matrix according to different data usage scenarios. The final utility for one side of transaction can be obtained from the top of the hierarchy by aggregating the direct and indirect value of the REBD.

III. DATA EVALUATION PROCESS BASED ON AHP

To get the objective functions of VEGA by REBD evaluation system established in Section II, four steps are needed:

1) Establish the REBD evaluation system for buyers and sellers and generate the initial scores of each probable transaction proposal;

2) After establishing the evaluation system, the process moves to the phase of forming the judgment matrix of each layer by using relative measurement method;

3) Derive relative weights for the various elements in each layer with respect to an element in the adjacent upper layer from judgment matrix;

4) The utility functions of buyers and sellers are formulated by aggregating the scores layer by layer according to the normalized vector of the overall weights.

In our work, the scores of each proposal should be dimensionless, namely, they can be added together according to their relative weights. Thus, the initial values of factors in criteria layer B are assessed by data analysis experts. The evaluation system is

$$x_i = (excellent, good, middle, qualified, unqualified) = (9, 7, 5, 3, 1).$$

The REGB transaction proposal is evaluated by the first criteria layer and formed as: $\vec{x} = [x_1, x_2, x_3, x_4, x_5, x_6]$. The value of factors in initial vector has an acceptable restricted interval for both buyers and sellers, all trading strategy proposed in REBD transaction cannot exceed this interval.

The construction of judgement matrix reflects the preferences of buyers and sellers with respect to the different factors in the same layer. To enable the decision maker to incorporate subjectivity, experience and knowledge in an intuitive and natural way, Santy's 1-9 scaling method [14-15] is used to set up the judgment matrixes between adjacent layers to assign the relative weights of each factors.

TABLE I

ASSIGNMENT INDEX OF JUDGMENT MATRIX'S ELEMENT

Scale	Scenes
1	The two factors are equally important
3	One factor is moderately more important than the other
5	One factor is strongly more important than the other
7	One factor is very strongly more important than the other
9	One factor is extremely more important than the other
2,4,6,8	Intermediate values for compromise between two successive qualitative judgments
Reciprocals	If the judgment of factor *i* relative to factor *j* is *a*, the reciprocal of *a* is the corresponding result when swapping the two factors

The judgment square matrixes between two adjacent criteria layers are obtained by simulating the preference of decision maker. We assume the direct value in criteria layer A is mainly affected by two factors in criteria layer B: integrity and real-time degree, the indirect value is mainly affected by integrity and sample coverage. The constructed judgment matrix of overall factors in criteria layer B with respect to the direct value and indirect value in criteria layer A are shown in following matrixes.

$$\begin{bmatrix} 1 & 1/2 & 1/2 & 1/6 & 1/4 & 1/4 \\ 2 & 1 & 3/2 & 1/2 & 3/4 & 3/5 \\ 2 & 2/3 & 1 & 1/3 & 1/2 & 1/2 \\ 6 & 2 & 3 & 1 & 3/2 & 3/2 \\ 4 & 4/3 & 2 & 2/3 & 1 & 1 \\ 4 & 5/3 & 2 & 2/3 & 1 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 2 & 1 & 1/3 & 1/3 & 2 \\ 1/2 & 1 & 1/2 & 1/4 & 1/6 & 1 \\ 1 & 2 & 1 & 1 & 1/4 & 2 \\ 3 & 3 & 1 & 1 & 1/2 & 4 \\ 4 & 6 & 4 & 2 & 1 & 6 \\ 1/2 & 1 & 1/2 & 1/4 & 1/6 & 1 \end{bmatrix}$$

Since deviations may occur during jugging the relative importance of two factors, which may lead to contradictions in judgment matrixes. In this paper, the consistency test of the relative weights is carried out to evaluate the consistency of judgment matrix. The concordance indexes of two pairwise comparison matrixes are calculated.

$$C.I._{direct} = \frac{\lambda_{\max} - n}{n-1} = 0.0038 \tag{1}$$

$$C.I._{indirect} = \frac{\lambda_{\max} - n}{n-1} = 0.0222 \tag{2}$$

where $\lambda_{\max}$ represents the largest eigenvalue of judgment matrix, n represents the dimension of judgment matrix. The lower consistency indicator value represents the judgment matrix has a better consistence. Since both concordance indexes are less than 0.1, the two judgement matrixes pass the consistency test. Thus, relative weights of factors in criteria layer B with respect to the two factors in criteria layer A can be computed as the components of the normalized eigenvector associated with the largest eigenvalue of their comparison matrix. The relative weights regarding the direct value and indirect value are

$$(0.054,\ 0.136,\ 0.100,\ 0.301,\ 0.201,\ 0.208),$$
$$(0.114,\ 0.060,\ 0.132,\ 0.216,\ 0.418,\ 0.060).$$

According to above procedure, the properties of each proposal are calculated and added up layer by layer, and the outcome of evaluation system is

$$v(\vec{x}) = \sum_{i=1}^{2} W_i \left(\sum_{j=1}^{6} W_{ij} x_j \right) \tag{3}$$

where $\vec{x}$ represents initial score vector of transaction proposal, W_i represents the relative weight of factor i in criteria layer A with respect to the final value of REBD, W_{ij} represents the relative weight of factor j in criteria layer B with respect to factor i in criteria layer A.

The factors in layer A have different importance for buyers and sellers due to various usage scenario. Based on this idea, we assume the relative weights of direct value and indirect value for buyers is [0.2,0.8], the relative weights of direct value and indirect value for sellers is [0.3,0.7] in experimental trading scenario. The final evaluation result of buyer and seller can be obtained at the target layer.

$$v_{Buyer}(\vec{x_i}) = 0.099x_1 + 0.074x_2 + 0.109x_3 + 0.238x_4 + 0.396x_5 + 0.084x_6 \tag{4}$$

$$v_{seller}(\vec{x_i}) = 0.093x_1 + 0.084x_2 + 0.108x_3 + 0.246x_4 + 0.371x_5 + 0.099x_6 \tag{5}$$

IV. VECTOR EVALUATED GENETIC ALGORITHM BASED REBD TRANSACTION OPTIMIZATION

Based on the REBD evaluation results obtained in Section III, the problem of accessing win-win REBD transactions can be converted into a multi-objective optimization problem [16-17]. The optimization functions of multi-objective optimization problem are shown as follows:

$$\begin{cases} V-\min f(\vec{x_i}) = \left[\left| v_B(\vec{x_i}) - v_S(\vec{x_i}) \right| \right] \\ V-\max f(\vec{x_i}) = \left[v_B(\vec{x_i}), v_S(\vec{x_i}) \right]^T \\ st. \quad A_{i.min} < \vec{x_i} < A_{i.max} \end{cases} \tag{6}$$

where v_B is buyers' utility function in REBD transaction, v_S is sellers' utility function in REBD transaction which can be calculated according to formula (24) and (25) respectively. $A_{i.min}$, $A_{i.max}$ are the lower and upper limits of initial score vector of transaction proposal.

The objectives of this research include minimizing the gap between utility function of buyers and sellers and maximizing the profits that both trading parties gained in REBD transaction. To integrate these two objectives, vector evaluated genetic algorithm (VEGA) is used to solve the optimal solution from the all transaction proposals. Fig. 2 demonstrates the procedure of finding pareto solution based on VEGA.

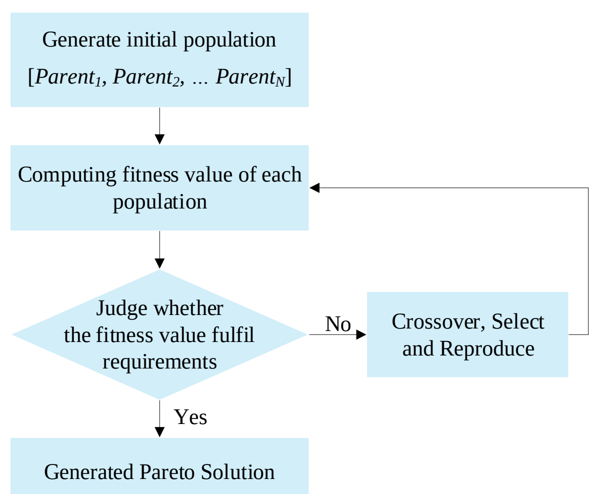

Fig. 2. Computing progress of solving optimal solution by VEGA

With the proposed algorithm, the initial population of transaction proposal is generated by random algorithm. Then, the fitness value of each population is evaluated based on (6). Population with high fitness are selected and put into the cross pool. After that, crossover operator was used to combine two parents and produce offspring for next generation [18]. The above process is executed in a loop until a Pareto solution with maximum fitness value is obtained. Based on this solution, buyers and sellers fulfill the transaction with an optimal price and dataset, which is called a win-win situation.

V. CASE STUDY

The historical transaction photovoltaic generation data in D5000 system in Sate Grid Corporation of China (SGSS) at Jiangsu Province is used as the experimental dataset. To validate the multi-objective optimization algorithm proposed in this paper, the big data transaction process is simulated by MATLAB. There are three groups of experiments executed in this paper. Each group contains 100 probable transaction proposals with different dimensionless transaction data factors. Based on the evaluation system established in Section II, the decision variables of VEGA can be calculated according the process proposed in Section III. The distribution of decision variables in sample 1 is demonstrated in Fig. 3.

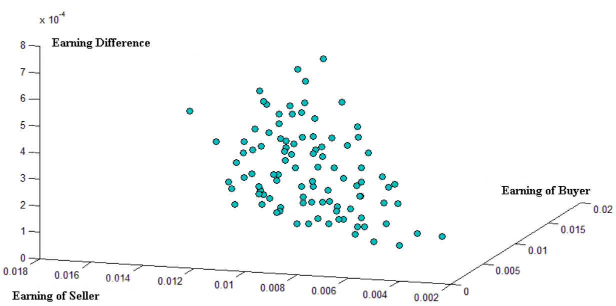

Fig. 3. Distribution of decision variables in data sample

In order to find global optimum solution in an efficient way, we set initial crossover probability $P_c = 0.5$, mutation rate of genetic algorithm $P_m = 0.1$ and maximum times of iterations 50. The optimal solution is obtained by computing the fitness value of the objective function. The non-inferior solutions obtained during three groups of experiments are shown in TABLE II.

TABLE II
PARETO SOLUTIONS OF THE VEGA EXPERIMENTS

Group Number	Simulation Result		
	Pareto Solutions		
1	[0.0196, 0.0052, 0.0167, 0.02, 0.0184, 0.0058]		
2	[0.0185, 0.004, 0.0157, 0.0202, 0.0195, 0.0149]		
3	[0.0138, 0.0152, 0.0121, 0.0176, 0.0165, 0.0200]		
	Earning of Seller	Earning of Buyer	Earning Difference
1	0.0152	0.0157	0.0004
2	0.0168	0.0171	0.0003
3	0.0166	0.0165	0.0001

TABLE II demonstrates the optimal solution obtained by the three groups of experiments has a high fitness for objective functions. The Pareto optimal solution maximize the earnings of both two sides in REBD transaction, simultaneously, minimize the earning difference between buyers and sellers. The simulation results verify that the proposed algorithm has global optimization ability in the renewable energy big data transaction.

VI. CONCLUSION

In this paper, a vector evaluated genetic algorithm (VEGA) based trading strategy optimization method was proposed to optimize the transaction process of REBD. Take all-round factors that influence the value of REBD into consideration, a four-layer hierarchy evaluation system is established based on analytic hierarchy process. Thus, the problem of accessing win-win REBD transactions can be converted into a multi-objective optimization problem. On this basis, vector evaluated genetic algorithm is used to solve this multi-objective optimization problem and find the pareto optimal solution. The pareto optimal solution can provide reasonable choices for decision maker by maximizing the earning of buyers and sellers. The effectiveness and robustness of the proposed approach is verified with delicately designed experiments.

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2. Application of Doubly Fed Induction Generators in Wind Power Generation, Electrotechnics Electric(Jiangsu Electrical Apparatus), 2012, 7
3. Overview of Permanent Magnetic Synchronous Motor Direct Torque Control, Electrotechnics Electric(Jiangsu Electrical Apparatus), 2012, 5

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