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Using improved iterative gravity method to optimize the investment location of agricultural biomass power generation projects: a case study

Biomass power generation has characteristics of good quality of power generation, high reliability and mature technology. It plays significant aspects in maintaining the safety of energy, optimizing energy structure, alleviating environmental pollution and promoting the economic development in the rural areas. Analyzing the investment of biomass power generation in China systematically cannot only improve the scientificity of the investment process, but also guide the industry to develop rapidly and healthily. At present, the investment areas of agricultural biomass power generation projects are too concentrated and the fuel supply is difficult, which affect the normal operation of biomass power plants and lead to loss or on the verge of profit and loss of biomass power generation plants. This paper constructed the optimal model of investment location of agricultural biomass power generation projects using the iterative gravity algorithm based on the key factors analysis to affect the operation costs of agricultural biomass power plants. The model optimized the transportation lines and transportation distance, and gained the smallest transport costs of power generation materials after a few iterative calculations. This paper took Huantai County as an example, and determined the optimal investment location of agricultural biomass power project using the Region props toolbox of Matlab 7.4. The simulating calculation of Huantai County showed that the results given by this model are reliable, and this method to select the investment location of agricultural biomass power projects is feasible and effective.

Keywords: Agricultural biomass power generation projects, investment location selection, optimized iterative gravity method, Huantai County.

1. Introduction

At present, energy shortage and environmental pollution has become the focus of common concern around the world, which is also an important problem must be faced of social and economic development in China. Biomass power generation is to generate power taking the biomass resources as raw materials, as a form of renewable energy power generation; biomass power generation technology is relatively mature, the power quality is good and reliability of the power generation is higher. Biomass power generation can be done without intermittent compared to the form of wind power and solar power. And biomass resource is abundant in China, more than 700 million tonnes of crop straw can be produced each year [1-5]. It is an effective way of making full use of biomass resources, alleviating environment pollution and increasing farmers' income to develop the biomass power generation.

Since 2005, the "Renewable Energy Law" and a series of supporting policies have been promulgated and implemented in succession, which promoted the rapid development of biomass power generation industry greatly. In some regions, resource reserves, climate environment and electric power market demand conditions are better, and many investors invested in the regions, which led to the locations of biomass power generation projects are too concentrated, the distance of biomass power generation projects is too close. Within a radius of 200 km in the north of Jiangsu province, a dozen biomass power generation plants were constructed, which cause the fuel resources shortage of biomass power generation inevitably, influence the normal operation of biomass power plants, lead the biomass power generation plants to loss or on the verge of profit and loss. Therefore, the government should take effective measures to regulate the investment layout of biomass power generation projects [6-11].

Different investment locations are related to the construction investment costs of biomass power generation projects, the amount of available biomass fuels and the operating costs after the completion of biomass power plants. The gap of investment costs of biomass power generation projects in the same city or county is not large. The different profit levels mainly depend on the operating costs of biomass power generation plants. The generating costs of agricultural biomass power generation plants mainly include: biomass fuel costs, purchased power costs, water expenses, material

expenses, wage expenses, depreciation expenses, repairing expenses, administrative expenses and financial expenses. We gained the generating cost composition (Fig.1) based on the field research data of the agricultural biomass power plants have been put into operation. It can be found that the agricultural biomass costs account for more that 60% of total power generation costs.
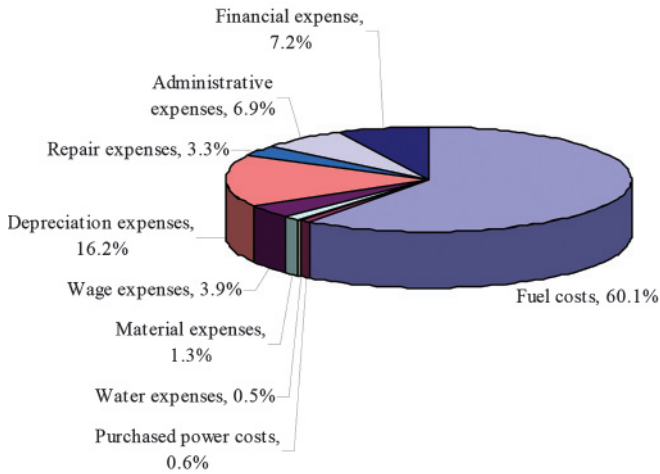

Fig.1 Power generation costs of the agricultural biomass power generation plants

The fuel costs of agricultural biomass power plants mainly include: purchase costs, processing costs, transportation costs, storage costs and wastage costs. The fuel costs composition is as shown in Fig.2, the fuel purchase costs account for 60% nearly of total fuel costs.
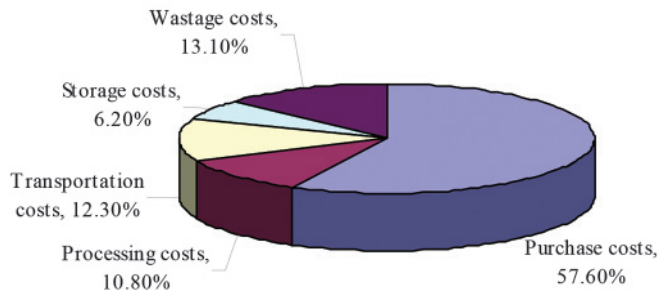

Fig.2 Fuel costs of the agricultural biomass power generation plants

The processing costs, storage costs and wastage costs are fixed in biomass fuel costs, the fuel purchase costs and transportation costs account for 69.9% of total fuel costs, account for 42.0% of total operation costs. The two costs can be reduced through the investment location selection of agricultural biomass power plants. The investment location selection of agricultural biomass power plants is systematic process, and a scientific and quantitative argumentation. There are many methods that have been widely applied to select the investment location, such as: analytic hierarchy process method, fuzzy evaluating method, etc. However, these methods are subject to stochastic factors in the calculation process, and the results are influenced by

subjective experience and knowledge limitations easily, which often with personal bias and one-sidedness. The gravity method can overcome the influence of subjective factors and has been applied widely. This paper will use the improved iterative gravity method to determine the optimal investment location of agricultural biomass power generation projects.

2. Methodology

2.1 THE BASIC PRINCIPLE OF GRAVITY METHOD

Gravity method is to determine the investment location through simulating the object gravity, and which is based on the principles of total minimum transportation cost [12-18]. We suppose the m distribution locations in different coordinate point (u_1, v_1). If the distribution center location is in coordinate point (u_0, v_0), the total transportation cost S can be expressed as follows:

$$S = \sum_{l=1}^{m} T_l W_l C_l \qquad \text{... (1)}$$

In formula (1), T_l denotes the transport costs from distribution center to distribution location l, W_l denotes the demands of distribution location l, C_l denotes the distance from demand location l to distribution center.

The distance C_l can be expressed as follows:

$$C_l = \sqrt{(u_l - u_0)^2 + (v_l - v_0)^2} \qquad \text{... (2)}$$

According to the gravity method, each distribution location has quality, the r_l expresses the equivalent weight of each particle, and the gravity center is the spot that the distance is shortest to the particles.

Thus, the logistics distribution center location is transferred to solve the bar centric coordinates.

We suppose,

$$r_l = T_l W_l$$

We define the equivalent weight of each particle is R, then

$$\sum_{l=1}^{m} T_l W_l C_l = \sum_{l=1}^{m} r_l C_l \qquad \text{... (3)}$$

Because of the geometry characteristics of the gravity center, the moment produced in UOV plane of equivalent weight in gravity center relative to the origin used to express as the following physical equation:

$$RC_0 = \sum_{l=1}^{m} r_l C_l = \sum_{l=1}^{m} T_l W_l C_l \qquad \text{... (4)}$$

We decompose the moment along the axis U and V:

$$\begin{cases} Ru_0 = \sum_{l=1}^{m} r_l u_l = \sum_{l=1}^{m} T_l W_l u_l \\ Rv_0 = \sum_{l=1}^{m} r_l v_l = \sum_{l=1}^{m} T_l W_l v_l \end{cases} \qquad \text{... (5)}$$

We input the formula (2) to formula (1), and got the

formula (6) through took partial derivative:

$$\begin{cases} \dfrac{\partial S}{\partial u_0} = \sum_{l=1}^{m} T_l W_l (u_0 - u_l) c_l = 0 \\ \dfrac{\partial S}{\partial v_0} = \sum_{l=1}^{m} T_l W_l (v_0 - v_l) c_l = 0 \end{cases} \qquad \text{... (6)}$$

Then we obtaine the most suitable u_0 and v_0, namely

$$\begin{cases} u_0 = \dfrac{\sum_{l=1}^{m} T_l W_l u_l / c_l}{\sum_{l=1}^{m} T_l W_l / c_l} \\ v_0 = \dfrac{\sum_{l=1}^{m} T_l W_l v_l / c_l}{\sum_{l=1}^{m} T_l W_l / c_l} \end{cases} \qquad \text{... (7)}$$

2.2 OPTIMAL SELECTION MODEL CONSTRUCTION BASED ON ITERATIVE GRAVITY METHOD

Iterative gravity method is also called differential method, which is proposed to overcome the shortcomings of gravity method. This method takes the result of gravity method as initial solution, and gets the exact solution by iteration [19-26]. This paper adopted the geometric center of agricultural biomass resource region to represent the entire region. We suppose then geometric centers of agricultural biomass resource regions to distribute in different coordinate points (x_i, y_i), and solve the initial solution (x_0, y_0) using gravity method. The computation formula is as follows:

$$\begin{cases} x_0 = \dfrac{\sum_{i=1}^{n} (a_i w_i x_i)}{\sum_{i=1}^{n} (a_i w_i)} \\ y_0 = \dfrac{\sum_{i=1}^{n} (a_i w_i y_i)}{\sum_{i=1}^{n} (a_i w_i)} \end{cases} \qquad \text{... (8)}$$

The total transportation costs can be expressed as:

$$C_0 = \sum_{i=1}^{n} (a_i w_i d_i) \qquad \text{... (9)}$$

In formula (9), a_i denotes the unit transportation costs from power generation plants to agricultural biomass resource region i, w_i denotes the resource transportation volumes from power generation plants to agricultural biomass resource region i, d denotes the straight line distance from power generation plants to agricultural biomass resource region i.

$$d_i = \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2} \qquad \text{... (10)}$$

The investment location selection should guarantee the lowest total transportation costs, and we suppose the C_0 is minimum:

$$\begin{cases} \dfrac{\partial C_0}{\partial x_0} = \sum \dfrac{a_i w_i (x_0 - x_i)}{d_i} = 0 \\ \dfrac{\partial C_0}{\partial y_0} = \sum \dfrac{a_i w_i (y_0 - y_i)}{d_i} = 0 \end{cases} \qquad \text{... (11)}$$

We can gain the (x^*_0, y^*_0), which is the iterative gravity solution:

$$\begin{cases} x^*_0 = \dfrac{\sum_{i=1}^{n} a_i w_i x_i / d_i}{\sum_{i=1}^{n} a_i w_i / d_i} \\ y^*_0 = \dfrac{\sum_{i=1}^{n} a_i w_i y_i / d_i}{\sum_{i=1}^{n} a_i w_i / d_i} \end{cases} \qquad \text{... (12)}$$

We input (x^*_0, y^*_0) to formula (8), gained the C^*_0 after the iteration, and compared to the original solutions C_0. If $C^*_0 < C_0$, then we continued to iterate; If $C^*_0 = C_0$, then we ended the operation, and the at this time is the optimal solution.

3. Results and discussions

Huantai county belongs to the Zibo City of Shandong province, which is located in the combination of mountainous area in the middle of Shandong and plains in the north of Shandong. Huantai county is the important commodity grain production base in China. Huantai county has 11 towns, the total area is 509 km^2, and the total planting area of crops is 49600 hm^2. In order to alleviate the environmental pollution brought by straw burning, increases the farmers' income and develop the rural economy, Huantai county proposed to develop the agricultural biomass power generation projects. The administrative division and straw resource yield distribution of Huantai county is shown in Fig.3.
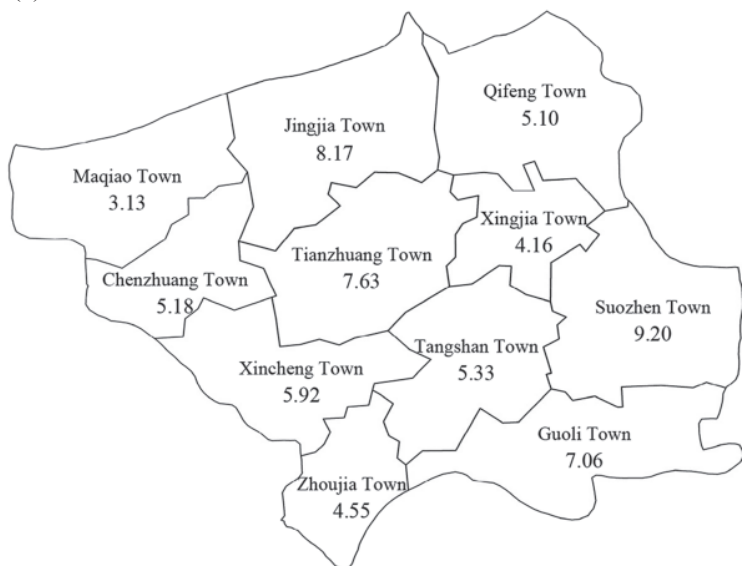

Fig.3 Administrative division and straw resource yield distribution of Huantai county
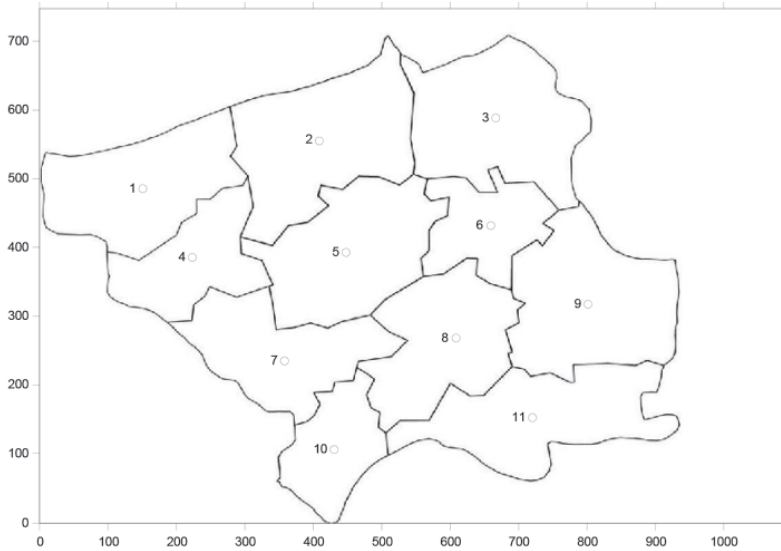
Fig.4 Geometric center locations of the towns in Huantai county

TABLE 1: GEOMETRIC CENTER COORDINATES AND STRAW RESOURCE YIELD
OF THE TOWNS IN HUANTAI COUNTY

Number	Towns	x_i	y_i	Straw yield (10^4 tonnes)
1	Maqiao Town	151	486	3.13
2	Jingjia Town	408	556	8.17
3	Qifeng Town	666	589	5.10
4	Chenzhuang Town	223	386	5.18
5	Tianzhuang Town	448	393	7.63
6	Xingjia Town	659	432	4.16
7	Xincheng Town	358	235	5.92
8	Tangshan Town	608	269	5.33
9	Suozhen Town	801	318	9.20
10	Zhoujia Town	430	106	4.55
11	Guoli Town	720	153	7.06

TABLE 2: ITERATIVE PROCESS AND OPERATION RESULTS OF THE
INVESTMENT LOCATION SELECTION OF THE AGRICULTURAL BIOMASS POWER
GENERATION PROJECTS

Iterative times	X	Y	C
0	522.99	354.57	15084.14
1	518.88	357.08	15077.32
2	515.90	358.65	15073.94
3	513.77	359.70	15072.24
4	512.25	360.44	15071.36
5	511.15	360.96	15070.91
6	510.37	361.33	15070.68
7	509.80	361.60	15070.56
8	509.40	361.79	15070.50
9	509.10	361.93	15070.47
10	508.89	362.03	15070.45
11	508.74	362.10	15070.44
12	508.63	362.16	15070.43
13	508.55	362.20	15070.43

We used the image processing function Region props in the software toolbox Matlab 7.4 to process the image of Fig.3, and we gained the geometric center of the townships in Huantai county. The geometric center locations of the towns in Huantai county are shown in Fig.4, and the geometric center coordinates and straw resource yield of the towns in Huantai county is shown in Table 1.

We suppose that the straw resource purchase price and the freight in unit distance are equal, then we can gain the total minimum transportation cost of the agricultural biomass power generation plants is 15070.43 after 13 times of iteration computation, the optimal investment location coordinate is (508.55, 362.20). The iteration process is shown in Table 2.

Through iterative calculation, we could get the optimal investment location (the red point) of
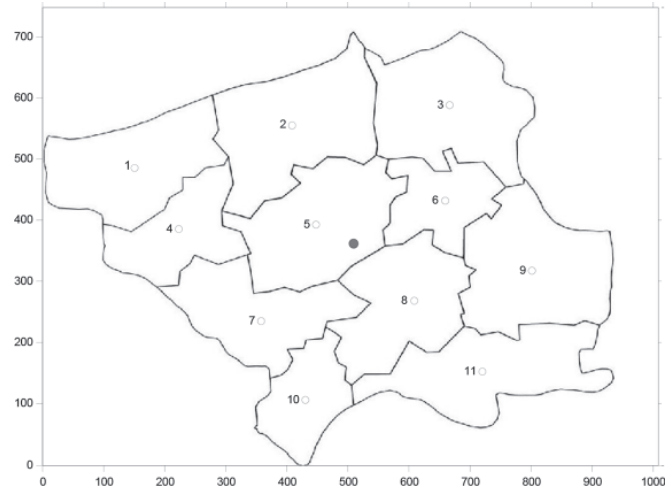

Fig.5 Optimal location of the agricultural biomass power generation project in Huantai county

agricultural biomass power generation projects in line with minimum transportation costs in Huantai county, which is as shown in Fig.5. The location is located in the outskirts of Huantai county, neither took up the urban construction lands, nor closed to main city supply networks, the line construction costs and infrastructure construction costs are low and the power plant staffing is more convenient, so it can be finalized for actual investment location.

4. Conclusions

The investment location selection of agricultural biomass power generation projects is associated with many factors, it needs large number of statistical calculations, and the factitious factors can be mixed into easily, which make the location selection work is difficult. On the basis of analyzing the important factors to affect the location selection of agricultural biomass power generation projects, we establish an optimal

model of investment location using the iterative gravity method and determin the optimal investment location of agricultural biomass power generation plants using the image processing function Region props through considering the number of biomass resources, fuel purchase costs, transportation costs and other key indexes. The simulation test results show that the iterative gravity method can simulate experts carrying out the optimal selection of investment location of agricultural biomass power generation projects.

5. Conflicts of interest

We declare that there is no conflict of interest regarding the publication of this article.

6. Acknowledgements

7. References

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