Research on the Mixed Multi-attribute Group Evaluation System of Integral Energy System of Industrial Park Based on SNA Analysis Method

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Abstract. At present, the system modeling of integrated energy system is a hot issue in the field of energy research. Most of the research focuses on the modeling of a specific regional energy system, but the research on the decision-making and evaluation system of integrated energy system is still in its infancy. Therefore, it is necessary to build a decision-making evaluation system for the whole process of the integrated energy system and design scientific evaluation indexes, methods and standards to evaluate the investment, construction, operation and benefits of the integrated energy system systematically and scientifically. On the basis of combing the existing research, this paper deeply analyzed the influencing factors of the whole process of regional integrated energy system, and excavated the factor association network through the social network analysis (SNA). After that this paper constructed the influencing factor association network of the whole process of the integrated energy system with the relationship between the factors as the network nodes. In order to provide reference for relevant research and project implementation, this paper identified the key indexes and built a hybrid index system of integrated energy system.

1. Introduction

With the vigorous rise of a new round of energy technology revolution, it is necessary to further develop new energy and realize the clean and efficient use of traditional energy. Integrated energy system emerges as the times require. As a complex energy system with industrial load as the main part, the energy demand of industrial park includes electricity, heat and other forms of energy, which is a comprehensive project in the process of integrated energy construction and plays an important role in promoting the development and improvement of integrated energy technology.

In literature [1], maturity assessment, it was shown that an environmental impact assessment and overall energy use and conversion efficiency assessment were proposed as macro evaluation criteria. Ming Z., Yingxin L. have established a regional integrated energy system benefit evaluation system with electricity as the core to reflect economic benefit, social benefit and environmental benefit from multiple indexes in the energy link, device link, distribution network link and user link[2]. An evaluation indexes and methods of micro energy system in the park has been established from the four aspects of economy, reliability, energy consumption and environmental protection by Shixiang, Z., Shuaikang, L.[3].

In the above researches, most of the indicators come from the evaluation of independent energy system or equipments. In fact, as a whole form of energy organization, the integrated energy system
needs to transcend the existing independent energy evaluation index system and establish a unified dimension to deeply tap the value of multi-energy complementary system.

2. Integrated energy system of industrial park and factors influencing its success

The integrated energy system of the industrial park considered in this paper belongs to the user level integrated energy system, which has a complete centralized cold, hot, gas and electric energy supply network. According to the field research on the regional integrated energy system project that has been carried out in China and the discussion with relevant experts, the influencing factors indexes of each stage in the four dimensions of economy, technology, society and management were determined[4-6].

| Table1. Factors affecting the whole life cycle of regional integrated energy system |
|---------------------------------|---------------------------------|---------------------------------|
| Target                          | Primary indices                | Secondary indices               |
|                                 | Economic indices               | Technical indices               |
| Project decision                | Economic indices               | Technical indices               |
|                                 | Economic indices               | Management indices             |
| Factors affecting the whole life cycle of regional integrated energy system | Economic indices               | Management indices             |
| Investment and construction     | Economic indices               | Management indices             |
| Operation and maintenance       | Economic indices               | Management indices             |
|                                 | Technical indices             | Economic indices               |
|                                 | Social indices                | Technical indices               |
|                                 | Social indices                | Political indices              |
|                                 | Social indices                | Social indices                 |

Effectiveness of economic benefit analysis(A1)  
Market price of raw materials(A2)  
Power supply reliability(A3)  
Comprehensive utilization rate of energy in the park(A4)  
Sustainable level of regional energy(A5)  
Planning project responsiveness(A6)  
Energy structure adjustment policy(A7)  
Macroeconomic environment(A8)  
Energy trading mode(A9)  
Communication management between the government and the park(A10)  
Design management system(A11)  
Quality of feasibility study preparation(A12)  
Claim for extra contract work(B1)  
Financial status of the construction party(B2)  
Project cost control(B3)  
Application of new technology and equipment(B4)  
Project progress control(B5)  
Project quality control(B6)  
Energy conservation and emission reduction policies(B7)  
Project management risk(B8)  
Project safety management(B9)  
Contract performance(B10)  
Completion acceptance management(B11)  
Operation and maintenance cost(C1)  
Purchased energy Cost(C2)  
Cost of technical transformation(C3)  
Equipment purchase cost(C4)  
Expected value of system energy deficiency(C5)  
Project defect management(C6)  
Energy supply network loss index(C7)  
Equipment utilization(C8)  
Changes in employment(C9)  
Customer satisfaction index(C10)  
Contribution to social and economic development(C11)
3. Mixed Multi-attribute Group Evaluation System Based on SNA Analysis Method

This section took the influencing factors of each stage of the whole life cycle of the integrated energy project as the research object, excavated the associated network through the social network analysis method (SNA) and carried out the associated analysis on the influencing factors.

3.1. Screening of key factors in integrated energy projects

According to the calculation relationship between the indicators, this paper determined the correlation path between the indicators and the correlation path coefficient between the two constituted the adjacency matrix of the correlation network; finally, this paper generated the power transmission and transformation project decision-making factor correlation network.

Based on the network adjacency matrix, the core elements of the network were analyzed from the point centrality and the intermediate centrality. For the network graph, the calculation formulas of centrality $C_d(v_i)$ of node $v_i$ and centrality $C_b(v_i)$ of betweenness were as follows:

$$C_d(v_i) = \sum_j a_{ij}$$

$$C_b(v_i) = \sum_{j \in \text{neighbor}} \frac{n_{st}(i)}{n_{st}}$$

In the formula, represented the connection state of nodes i and j. When i≠j and nodes i and j had edges connected, $a_{ij} = 1$ otherwise $a_{ij} = 0$; $n_{st}$ was the shortest path between nodes $v_s$ and $v_t$, and $n_{st}(i)$ is the shortest path between nodes $v_s$ and $v_i$ passing through node $v_t$. Finally, by judging the centrality of point degree and the centrality of intermediate number of different elements, the elements with low centrality were filtered out, and the remaining elements were the key indicators in the associated network.

3.2. The analysis of mixed multi-attribute group index association network

In this section, according to the research results of the evaluation index system of regional integrated energy system in the previous section, the relationship network of influencing factors in each stage was as follows:

(1) Related network of influencing factors in project decision-making stage

According to the incidence relation of formula (1) and (2), it calculated centrality and centrality of SNA. The results were as follows:

| No. | Influencing factors                             | $C_d(v_i)$ | $C_b(v_i)$ |
|-----|------------------------------------------------|------------|------------|
| 1   | Effectiveness of economic benefit analysis     | 2          | 0.5        |
| 2   | Market price of raw materials                  | 1          | 0          |
| 3   | Power supply reliability                       | 4          | 0.86       |
| 4   | Comprehensive utilization rate of energy in the park | 3       | 0.75       |
| 5   | Sustainable level of regional energy           | 2          | 1          |
| 6   | Planning project responsiveness               | 1          | 0          |
| 7   | Energy structure adjustment policy            | 3          | 0          |
Finally, it was selected power supply reliability, comprehensive utilization rate of energy in the park, sustainable level of regional energy, macroeconomic environment, quality of feasibility study preparation as the key decision-making factors.

(2) Related network of influencing factors in the investment and construction stage

The results were as follows:

Table 3. The central calculation results in the investment and construction stage

| No. | Influencing factors                                           | $C_d(v_i)$ | $C_b(v_i)$ |
|-----|--------------------------------------------------------------|------------|------------|
| 1   | Claim for extra contract work                               | 1          | 0          |
| 2   | Financial status of the construction party                  | 2          | 1          |
| 3   | Project cost control                                        | 4          | 0.71       |
| 4   | Application of new technology and equipment                 | 2          | 0          |
| 5   | Project progress control                                    | 3          | 1          |
| 6   | Project quality control                                     | 3          | 1          |
| 7   | Energy conservation and emission reduction policies         | 2          | 0          |
| 8   | Project management risk                                     | 2          | 0          |
| 9   | Project safety management                                   | 5          | 0.5        |
| 10  | Contract performance                                        | 2          | 0.5        |
| 11  | Completion acceptance management                            | 2          | 0.5        |

Finally, it was selected project cost control, project progress control, project quality control, project safety management as the key decision-making factors.

(3) Related network of influencing factors in the operation and maintenance stage

The results were as follows:

Table 4. The central calculation results in the operation and maintenance stage

| No. | Influencing factors                                          | $C_d(v_i)$ | $C_b(v_i)$ |
|-----|--------------------------------------------------------------|------------|------------|
| 1   | Operation and maintenance cost                              | 3          | 1          |
| 2   | Purchased energy Cost                                       | 3          | 1          |
| 3   | Cost of technical transformation                            | 1          | 0          |
| 4   | Equipment purchase cost                                     | 1          | 0          |
| 5   | Expected value of system energy deficiency                 | 1          | 0          |
| 6   | Project defect management                                   | 2          | 0.5        |
| 7   | Energy supply network loss index                            | 3          | 1          |
| 8   | Equipment utilization                                       | 1          | 0          |
| 9   | Changes in employment                                       | 2          | 0          |
| 10  | Customer satisfaction index                                 | 3          | 0.75       |
| 11  | Contribution to social and economic development             | 2          | 0.5        |
| 12  | Financial evaluation index                                  | 5          | 0.87       |
| 13  | Energy economy level                                        | 2          | 0          |
Finally, it was selected operation and maintenance cost, purchased energy cost, energy supply network loss index, customer satisfaction index, financial evaluation index, emission level of environmental pollution as the key decision-making factors.

3.3. The mixed multi-attribute group evaluation index system of regional integrated energy projects

This section constructed the evaluation index system of regional integrated energy project investment benefit based on the measurement of key influencing factors, including three parts: target layer, evaluation layer and operation layer. Among them, the evaluation stage was the stage module selected according to the actual operation of the integrated energy project; the operation level was the final index of the terminal value obtained through data collection or scoring. Through establishing the index system, the evaluation implementation subject could flexibly select the content of the index system to treat the evaluation object for all-round and multi-dimensional evaluation and diagnosis according to the different situations of the project.

Table 5. The mixed multi-attribute group evaluation index system

| Target layer | Evaluation layer | Operation layer |
|--------------|-----------------|-----------------|
| Project decision | Power supply reliability | Project cost control |
|               | Comprehensive utilization rate of energy in the park | Project progress control |
|               | Sustainable level of regional energy | Project quality control |
|               | Macroeconomic environment | Project safety management |
|               | Quality of feasibility study preparation | Operation and maintenance cost |
| Factors affecting the whole life cycle of regional integrated energy system | Investment and construction | Purchased energy Cost |
|               | Energy supply network loss index | Energy supply network loss index |
|               | Customer satisfaction index | Purchased energy Cost |
|               | Financial evaluation index | Energy supply network loss index |
|               | Emission level of environmental pollution | Emission level of environmental pollution |

4. Conclusion

This paper took the integrated energy project of the industrial park as the object, and put forward 14 mixed multi-attribute group evaluation systems of the integrated energy system of the secondary industrial park, including four first level indicators of economy, technology, management and society, and the investment cost. This index system covered the whole process of integrated energy from project decision-making to operation and maintenance. It can systematically and comprehensively analyze the energy efficiency, cost-effectiveness, energy supply quality and environmental impact of the integrated energy system; it can be used to optimize one or several performance indexes for system planning, so as to maximize the economic, environmental and social benefits of the integrated energy system.

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