The Empirical Research of Multi-energy Micro grid Operation Efficiency Based on DEA Method

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Abstract. At present, China is striving to build a modern energy system, and the integrated energy system is regarded as the key technology to be promoted. As an important technology for the implementation of the integrated energy system, the operation of multi-energy micro grid should also be studied. Based on the above ideas, this paper studies the efficiency evaluation method of multi-energy micro grid. Firstly, a dynamic and static multi-energy micro grid operation efficiency evaluation index system is constructed. According to the characteristics of the index system, DEA method is used for evaluation. Finally, an example is designed to carry out empirical research.

1. Different types of multi-energy supply and demand characteristics in smart cities

As the implementation form of the integrated energy system at the present stage, the evaluation of its operation efficiency should also be oriented to promote energy reform, so that the evaluation results can better guide the planning and operation of the multi-energy micro grid. Operational efficiency represents the ratio of input to output in the operation process of the system. In the operation process of multi-energy micro grid, it is necessary to strive to achieve the maximum output with the minimum input, which is reflected in the indicator system and evaluation process, namely, the two-way optimization of input (input) index and output (output) index. Therefore, the basis of index classification is:

First, considering the energy more general characteristics of micro network, this paper will all indicators divided into economic efficiency, energy efficiency and service level, three major categories, economic efficiency is used to depict the project investment and income situation, energy utilization, energy efficiency is used to analyze the system service level indicator is used to reflect system of all kinds of comprehensive energy users in the zoo their support;

Second, according to the basic requirements of general efficiency evaluation, this paper divides the indexes into two categories: input indexes which represent the initial conditions of system operation, and output indexes which represent the results of system operation.

Thirdly, according to the index value, the index with a larger value and better value is set as a positive indicator, while the index with a smaller value and better value is set as a negative indicator.

Indicators whose value is a single fixed value are determined as static indicators, and indicators whose value varies with time and values in different time periods are determined as dynamic indicators. The dynamic indicators in this paper are evaluated once every hour and calculated according to the 24-hour schedule.

Based on the above analysis and the basic characteristics of multi-energy micro grid structure and operation mode, the comprehensive evaluation index system is constructed in this chapter, as shown in table 1.

Table 1. Evaluation Index System

The Classification Of Index	The name of index	The attribute of index	The characteristics of index	dynamic/ statics
Economic indicators	Investment cost	Input index	Negative direction	Static index
	Internal rate of return	Output index	Forward direction	Static index
	Payback period	Output index	Negative direction	Static index
Energy efficiency	Wind abandoning rate	Output index	Negative direction	Static index
	Light abandoning rate	Output index	Negative direction	Static index
	Line loss rate	Output index	Negative direction	Static index
	Callable Load Ratio	Input index	Forward direction	Dynamic index
	Prediction accuracy of block energy demand	Input index	Forward direction	Dynamic index
	Coupling Conversion Efficiency	Input index	Forward direction	Static index
	Transport and Storage Efficiency of Independent Devices	Input index	Forward direction	Static index
	Primary Energy Utilization Rate	Input index	Forward direction	Dynamic index
	Terminal Energy Utilization Rate	Output index	Forward direction	Dynamic index
Service level	Pollutant Emission Rate	Output index	Negative direction	Static index
	Reliability of energy supply	Output index	Forward direction	Dynamic index
	Energy supply stability	Output index	Forward direction	Dynamic index
	User Satisfaction	Output index	Forward direction	Static index
	Extension rate of integrated energy services	Output index	Forward direction	Static index

Considering the applicability of the indicator system, all the economic efficiency indicators and most of the energy efficiency indicators in this paper can be obtained through the direct collection and simple processing of system operation data, but the specific calculation methods of some indicators need further explanation:

(1) Callable load ratio. Represents the percentage of the total load available for invocation. Callable load refers to the load reduction within a specified time period to smooth the peak load or increase the load level to absorb the clean energy load according to the system scheduling requirements.

(2) Prediction accuracy of block energy demand. The system is further subdivided into blocks. In the process of energy demand prediction, the energy demand of each block in each time period is predicted. The value of this index is the average of the accuracy of energy demand prediction in all blocks in all time periods.

(2)Coupling conversion efficiency. Refers to the conversion efficiency between water, electricity, heat and gas in an integrated energy system.

(3)Transmission and storage efficiency of independent devices. This index represents the transmission efficiency of energy supply equipment during transmission minus transmission loss and the storage efficiency during energy storage and release [20].

(4) Reliability rate of energy supply. The calculation method is similar to the power supply reliability rate, which is the expansion of the power supply reliability rate:

$$SR = (1 - \frac{T_S}{T_T})$$

Where SR is the energy supply reliability rate, TS is the average energy outage time for users, and TT is the time during the statistical period. As long as there is a terminal energy supply, it is considered that the energy supply.

(5) Stability of energy supply. The voltage stability index is used to describe the energy supply quality of the system.

(6)Promotion rate of comprehensive energy services. The proportion of users participating in integrated energy services in the system.

2. DEA model

Data Envelopment Analysis (DEA) is a kind of non-parametric efficiency evaluation method, and the relative efficiency is the basis for the evaluation and decision-making of this method. This method mainly analyzes and calculates the relationship between multiple input indexes and output indexes through mathematical means, and evaluates the effectiveness of the production, operation and other fronts of the same type of decision-making unit. DEA method, from the perspective that it is most beneficial to the decision evaluation of decision making unit, can effectively reduce the interference of other influencing factors on the calculation results, and the accuracy of efficiency evaluation results is higher.

DEA belongs to the linear programming method. In the calculation process, the method first forms piecewise curve combination by connecting the efficiency advantages of the production front surface, and then obtains the convex production possibility set, which contains all the efficiency advantages. Therefore, under the condition that the input indicator data (i.e., the production input of the decision making unit) remains unchanged, the output indicator on the optimal efficiency of the set is optimal (or the highest output). Similarly, when the output indicator (that is, the production output of the decision making unit) remains unchanged, the input indicator on the optimal efficiency of the set is optimal (or the lowest production input).

Compared with other evaluation methods, DEA model is suitable for operation efficiency evaluation of multi-energy micro grid. The reasons are as follows.

First, DEA model can comprehensively consider the articulation between input and output indexes in the calculation process, which is applicable to the complex comprehensive evaluation of multiple input-multiple output indexes of decision making unit. However, multi-energy micro grid is a comprehensive evaluation problem that includes multi-type energy production, transmission and transformation, consumption, storage and other links, and has the characteristics of multi-input and multi-output indicators, so it is consistent with the applicable scope of DEA model.

Secondly, there is no direct relationship between the efficiency calculation process of DEA model and data dimension, so index data can be directly substituted into the model for calculation without dimensionless processing. In this aspect, the evaluation data of multi-energy micro grid operation often differ greatly in dimensionality. There are many indexes such as operation cost, planning cost and load rate. The use of DEA model will significantly eliminate the impact of data dimensionality gap on the calculation results, so it is a relatively applicable method.

Thirdly, DEA does not need index weighting processing. The index weight of DEA model is obtained by solving linear programming, which is completely based on index data information and eliminates artificial weighting interference. Therefore, DEA efficiency evaluation is relatively fair. However, objectivity is one of the important conditions for the operation efficiency evaluation of multi-energy micro grid, so the DEA method is more suitable.

Fourth, DEA method does not need to clear through function expression checked relationship between input and output indicators, for more energy piconets, types of energy production, consumption, storage, transfer, transformation of related index correlation relationship, if at the same time, considering the relationship between the indicators will complicate the calculation process, and the DEA method can avoid this problem very well.

To sum up, this chapter will use DEA method to evaluate the operation efficiency of multi-energy micro grid.

3. Empirical analysis

Since there is currently no multi-energy micro grid in operation in China, this section selects four typical parks with distributed wind power, photovoltaic and cogeneration units in north China as objects, and USES CPLEX to solve DEA linear programming model to evaluate the operation efficiency of each park.

3.1. Basic Data

Through investigation, the static index data of the four parks are shown in table 2, and the dynamic index data are shown in figure 1 to 6.

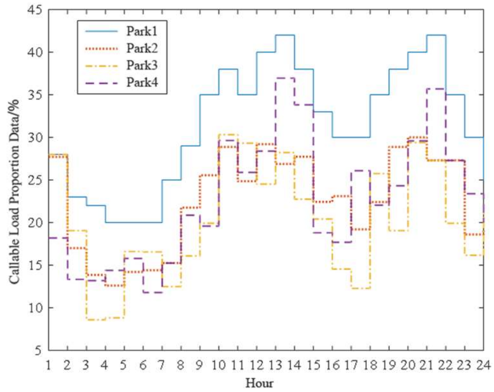

Figure 1. Callable Load Proportion Data for Various Solutions

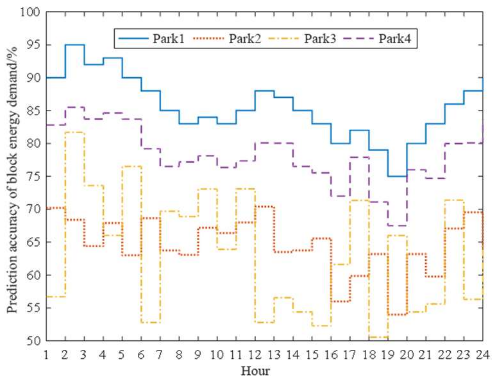

Figure 2. Accuracy rate of load forecasting for each scheme block

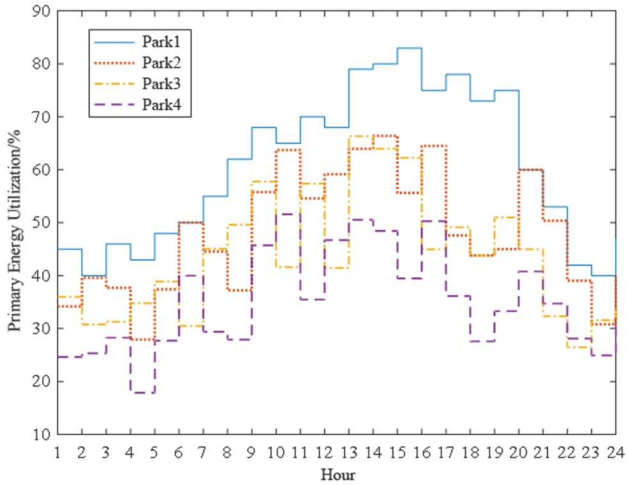

Figure 3. Primary Energy Utilization Rate of Various Solutions

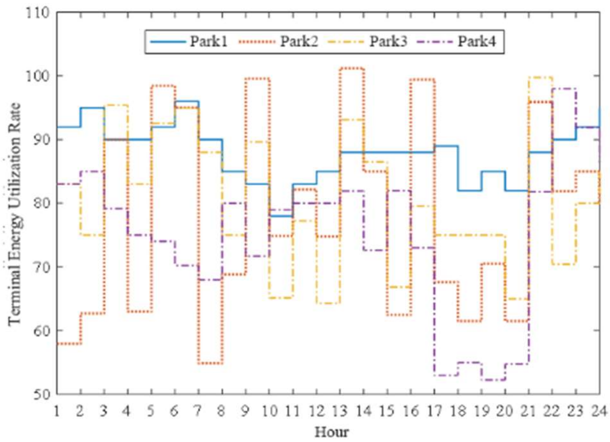

Figure 4. Terminal Energy Utilization Rate of Various Solutions

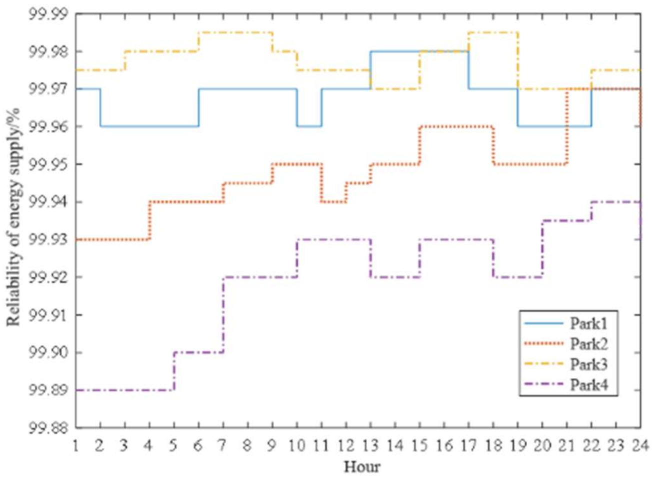

Figure 5. Reliability of energy supply of Various Solutions

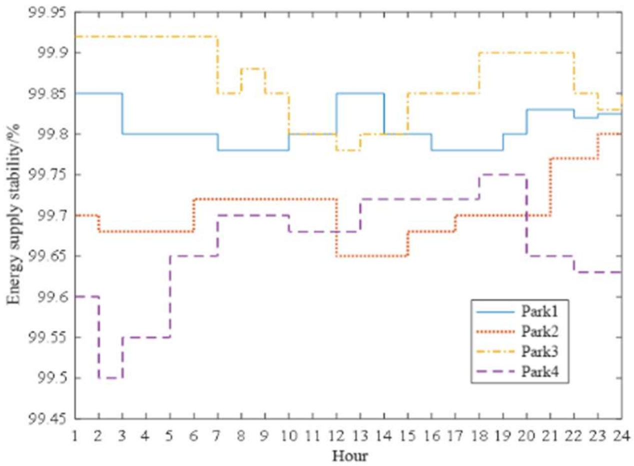

Figure 6. Energy supply stability

Table 2. Static Indicator Evaluation Index Data of Each Park

The Classification Of Index	The name of index	Park1	Park2	Park3	Park4
Economic indicators	Investment cost/10^8RMB	4.3	4.8	5	4.5
	Internal rate of return/%	20.2	21.1	18.9	25.4
	Payback period/Year	9.3	9.5	9.8	10.6
Energy efficiency	Wind abandoning rate/%	13.11	13.4	16.2	11.8
	Light abandoning rate/%	10.9	11.9	12.2	13.9
	Line loss rate /%	5.9	6.1	5.8	6.4
	Coupling Conversion Efficiency/%	74.1	85.3	77.6	75.2
	Transport and Storage Efficiency of Independent Devices/%	86.1	89.4	85.6	87.3
Service level	Pollutant Emission Rate/(g/kWh)	7.7	7.8	7.9	8.8
	User Satisfaction/%	92	95	90	88
	Extension rate of integrated energy services/%	90	90.5	83.4	75.3

3.2. Calculation result

Based on the improved three-stage DEA model proposed in this chapter, the index data is substituted into the model and Matlab software is used for calculation. The efficiency value of each scheme's static index is shown in table 3. According to the calculation results, the park 2 has the highest efficiency when only the static index is analyzed

Table 3. Efficiency Value of Static Indicators of Various Schemes

The name of index	Park1	Park2	Park3	Park4
Operational efficiency	0.986	1	0.958	0.969

On this basis, the dynamic index data can be substituted into the model to obtain the efficiency of each scheme in different time periods, as shown in figure 4. The total efficiency of the dynamic index of each scheme is shown in table 4.

Table 4. Efficiency Value of Dynamic Indicators of Various Programs

The name of index	Park1	Park2	Park3	Park4
Operational efficiency	0.989	0.977	0.936	0.946

It can be seen from table 3-3 that the dynamic index efficiency value of park 1 is the best. Taking the average value of static efficiency and dynamic efficiency of the four parks, it can be obtained that the efficiency of park 1 is 0.987, park 2 is 0.989, park 3 is 0.947, and park 4 is 0.946. It can be seen from the calculation results that the comprehensive operation efficiency of park 1 is the highest.

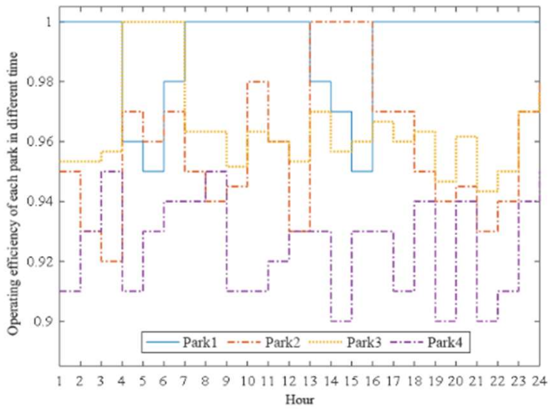

Figure 7. Operating efficiency of each park in different time

4. Conclusion

According to the research in this paper, firstly, as multi-energy micro grid is characterized by multi-energy complementarity and multi-energy coupling and coordination, improving the mutual conversion efficiency between multiple energy sources is the key to improving the operation efficiency of multi-energy micro grid. Second, to improve users' energy use experience and improve customer service level is also an important starting point to improve the operation efficiency of multi-energy micro grid. Thirdly, in the process of system operation, no matter the existing park system or the multi-energy micro grid constructed in this paper, it is necessary to make full use of users' comprehensive energy resources to reduce the system's peak load and absorb clean energy. Meanwhile, primary energy utilization rate and terminal energy utilization rate can be improved by relying on multi-energy complementarity and optimal allocation.

References

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