Simulation of Multi-area Integrated Energy for Cooling, Heating and Power Based on Large Data Analysis

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Abstract. Because the current power supply does not take into account the regional climate cold and hot issues, leading to some areas of power energy supply is greater than demand, waste a lot of unnecessary electricity, power utilization rate is low. To solve the above problems, a multi-area integrated energy dispatching method based on large data analysis is proposed. Firstly, the data warehouse method is used to integrate the supply and demand data of multi-region related comprehensive energy sources, then the integrated data is processed, and then the power demand level is divided based on fuzzy clustering. Finally, the multi-region power is reasonably supplied according to the level, and the comprehensive energy dispatch of cooling, heating and power is completed. The experimental results show that the multi region integrated energy scheduling method based on big data analysis can reduce the average power supply power by 353.534 kW, and improve the utilization rate of electric energy.

Keywords: Largedata analysis · Integrated energy of cooling · Heating and power · Integrated energy dispatch · Simulation

1 Introduction

Under the double pressure of energy crisis and environmental pollution, the construction of regional comprehensive energy system has attracted wide attention all over the world. Compared with the traditional cold, hot and power distribution system, the regional comprehensive energy system has higher energy utilization efficiency and emission reduction value [1]. In China, the construction of regional comprehensive energy system is still in its infancy, and the scientific planning and optimal allocation of regional comprehensive energy supply system is of great significance to its optimal operation and overall performance improvement, which is an important problem to be solved in the further development of regional comprehensive energy system in China. The regional comprehensive energy system is composed of two parts: energy station and heat and cold transmission pipeline network. Integrated energy station is the core of regional integrated energy system. Its design process can be divided into three parts: basic architecture design, equipment combination optimization and decision-making based on operation simulation. The basic structure design is to determine the type of the

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alternative cold and heat power conversion device and its connection relationship according to the primary energy status, site, energy supply type and demand of the user demand and other elements available in the area. The process of equipment combination optimization is similar to that of power supply planning. Generally, operation simulation is used to optimize the comprehensive energy equipment type, capacity and number combination to achieve the optimal goal. When considering the multi-objective of economy and environmental protection, it is also necessary to obtain the recommended scheme through the comprehensive decision-making process.

With the continuous complexity of the structure and function of the power grid, the requirements for the economy, environmental protection and reliability of the power system are getting higher and higher. How to improve the energy utilization rate, improve the energy structure of the power system, alleviate the contradiction between energy demand and energy shortage, energy utilization and environmental protection, and make the power grid move towards a clean, safe, efficient and reliable development path has become a difficult problem and key to power operation [2]. China has a vast territory and occupies many temperature zones. Therefore, there are some differences in temperature in each region. Therefore, in summer indoor cold supply and winter indoor heat supply, according to the regional temperature, is one of the main ways to solve the above problems [3]. However, how to realize the rational dispatch of multi-regional integrated energy resources of cooling, heating and power, the large data analysis in the early stage is very important, and it is the basis of realizing the rational distribution of power energy. In the process of big data analysis, it mainly includes data acquisition related to regional energy supply, then processing the collected power data, dividing the power supply and consumption of multi-region into several levels according to the actual demand of local power, and finally realizing the optimal distribution of power according to the level, reasonable dispatch, in order to reduce unnecessary consumption of power energy and improve the energy structure. In order to validate the effectiveness of the multi-region integrated energy dispatching method based on large data analysis in this study, a simulation experiment was carried out. The results show that the total energy supply in North China has been greatly reduced after using this method to dispatch the integrated energy of the region. This shows that the utilization rate of power energy has been improved and the energy shortage has been alleviated.

2 Multi-area Cooling, Thermoelectricity and Integrated Energy Dispatch

With the rapid development of social science and technology, human living and development space is more and more vulnerable to population growth, energy shortage, environmental pollution and ecological destruction [4]. In order to improve energy efficiency, reduce environmental pollution and improve energy structure, countries around the world have made the exploration of alternative energy sources and the sustainable development of energy as a top priority. With the rapid economic growth and social development in China, the contradiction between energy demand and energy shortage, energy utilization and environmental protection has become increasingly prominent. With its cleanliness and renewability, electric energy has become the focus of research. It has more and more advantages in improving energy utilization efficiency, developing new energy and alleviating energy demand. It is of great significance to solve the contradiction between economic development and environmental constraints in China [5]. At present, as one of the core technologies in the field of power utilization, there are still many problems to be solved. On the one hand, to meet the requirements of power system security, reliability and economy, it is the key and difficult point in the field of power supply to study the optimal dispatching methods and strategies [6]. On the other hand, with the increase of the permeability of renewable power generation, it is of great practical significance to reduce the impact of randomness and fluctuation of renewable power generation on the system by using power energy optimal dispatching technology.

2.1 Data Integration of Supply and Demand for Integrated Cooling, Thermal and Power Energy Based on Multi-regional Relevance

In the power regulation business, there are many business systems, such as power information collection, geographic information, distribution automation, dispatching automation, production management, weather forecast, marketing and so on. These systems describe the information of an object from different perspectives. At present, the information is independent, that is, multiple files of an object. In order to extract more valuable information from regulatory data, it is necessary to integrate descriptive information from multiple perspectives of an object and conduct joint analysis to realize one object, one file, one device, one file, one user, one event and one file. For this reason, it is necessary to adopt a unified data model, data structure and association relation oriented to power grid object, and integrate and manage these data to support large data analysis and calculation. In order to solve this problem, this chapter studies data integration [7].

Data integration is the integration of data from several different data sources into a unified data set, which may be integrated logically or physically. The core task of data integration is to integrate related distributed heterogeneous data so that users can access them transparently. Common data integration methods include federated database system, middleware integration method and data warehouse method. In this paper, the data warehouse method is used to integrate the supply and demand data of multi-region related integrated cooling, heating and power energy, so this method is only described below [8].

The data warehouse method is to establish a data warehouse to store data. As shown in Fig. 1, what it actually does is copy data from each data source to the same place, that is, data warehouse.

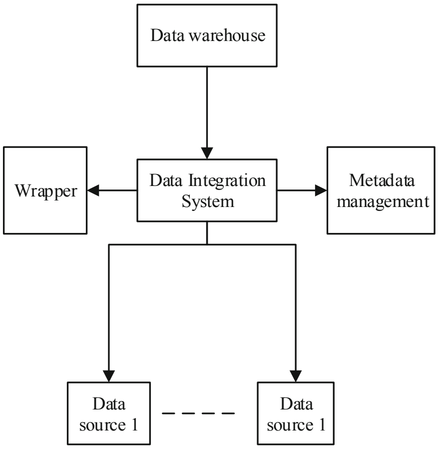

Fig. 1. Data warehouse

In order to extract the existing data sources and organize them into the form of comprehensive data that can be used for decision analysis, the basic architecture of a data warehouse should have the following basic components:

(1) Data source. Operational database systems and external data that provide the lowest level of data for data warehouses [9].
(2) Monitor. Responsible for sensing changes in data sources and extracting data according to the needs of data warehouse.
(3) Integrator. The data extracted from the operational database are transformed, computed, synthesized and integrated into the data warehouse.
(4) Data warehouse. Store data that has been converted according to the enterprise view for analysis and processing. According to different analysis requirements, data are stored in different degrees of integration. Metadata should also be stored in the data warehouse, which records the data structure and any changes in the data warehouse to support the development and use of the data warehouse.
(5) Customer applications. Provides a tool for users to access and query data in data warehouse, and expresses the results of analysis in an intuitive way [10].

2.2 Data Processing of Supply and Demand for Integrated Energy of Cooling, Heat and Power

Data integration is followed by data processing steps, and data cleaning operations are usually required in actual business processes. Usually, dirty data exists in business systems, including incomplete data, wrong data and duplicate data. Therefore, data cleaning technology is needed to deal with these dirty data [11]. Common data cleaning methods are given below:

(1) Solutions to Incomplete Data

In most cases, missing values need to be filled in manually; some missing values can also be derived to approximate values, which can be replaced by average, minimum, maximum or other more complex probability estimates.

(2) Method of detecting error values

Statistical analysis can be used to detect possible error values, or simple rule bases can be used to detect data values, or constraints between different attributes can be used to detect error values [12].

(3) Detection and elimination of duplicate records

If all attribute values of both records are the same, the two records are duplicated. The purpose of eliminating duplicate records can be achieved by retaining one of the records.

(4) Detection and elimination of inconsistent data

By defining integrity constraints, inconsistent data can be detected, and connections can be found by analyzing data. Cleaning can be done by specifying simple transformation rules or using domain-specific knowledge [13].

2.3 Power Demand Classification Based on Fuzzy Clustering

Fuzzy clustering analysis is a method of clustering objective things according to their characteristics, degree of affinity and similarity [14]. Its characteristics are that the conclusion of fuzzy clustering does not mean that the objects belong to a certain category absolutely, but that the objects belong to a certain category relatively with clear values. To a certain extent, it belongs to another category. In the fuzzy clustering analysis, the first step is to calculate the fuzzy similarity matrix, and different fuzzy similarity matrices will produce different classification results; even if the same fuzzy similarity matrix is used, different thresholds will produce different classification results [15, 16]. The basic steps of power demand classification based on fuzzy clustering are shown in Fig. 2 below.

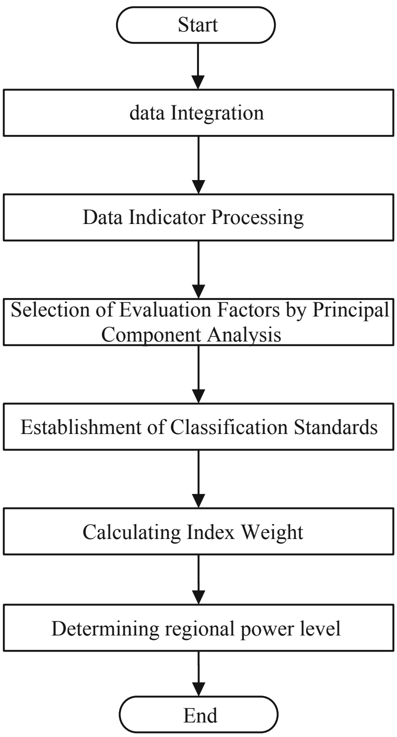

Fig. 2. Basic steps of power demand classification based on fuzzy clustering

The first step is to process the statistical indicators of each representative point, in order to make the data of each indicator comparable, the dimensionless processing is carried out. Dimension is an important concept in physics. In theoretical calculation and numerical calculation, it is often necessary to do dimensionless processing (in fact, the main characteristic quantities of the system are used as the units of the corresponding physical quantities). By doing so, the theoretical calculation is simple, the numerical calculation is convenient, and the physical equation can be transformed into a specific mathematical equation, which is convenient for mathematical processing. The extremum method is chosen here to be dimensionless.

There are three ways to choose:

$$x_i' = \frac{x_i}{\max - \min} \tag{1}$$

That is to say, every variable is divided by the total distance of the value of the variable, and the value range of each variable after standardization is limited to [−1,1].

$$x_i' = \frac{x_i - \min}{\max - \min} \tag{2}$$

That is to say, the difference between each variable and its minimum value is divided by the total distance of the value of the variable, and the range of the value of each variable after standardization is limited to [0,1].

$$x_i' = \frac{x_i}{\max} \tag{3}$$

That is, the value of each variable is divided by the maximum value of the variable, and the maximum value of the variable is 1 after standardization.

Dimensionalization of variable data by extremum method is to transform original data into data bounded by a specific range through the maximum and minimum values of variable values, thus eliminating the influence of dimension and order of magnitude.

The second step is to select evaluation factors by principal component analysis. The process is shown in Fig. 3 below.

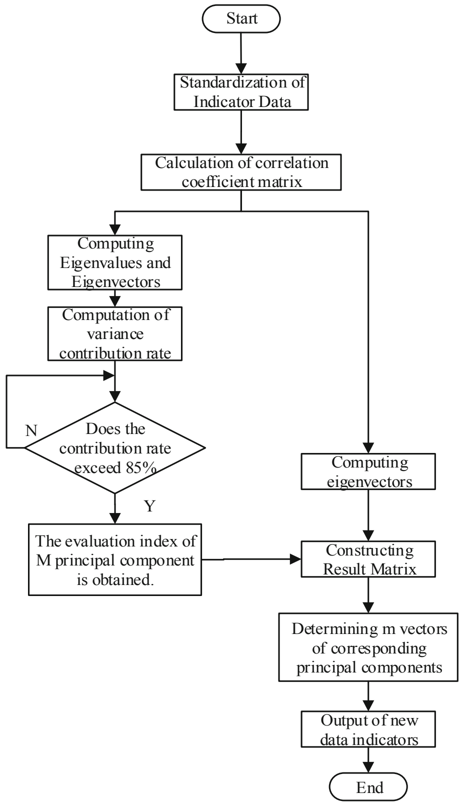

Fig. 3. Selection of evaluation factors by principal component analysis

The third step is to establish the classification standard. Table 1 below is the power demand classification standard.

Table 1. The power demand classification standard

Power demand level	Electricity demand (KW)
Level 1	[500,1000)
Level 2	[1000,2000)
Level 3	[2000,3000)
Level 4	[3000,4000)
Level 5	[4000,5000)

Next, we need to convert the standard of fuzzy disaster degree classification to Table 1. The purpose is to establish the membership function of the fuzzy set of disaster loss grade, and to unify the standard of dividing the loss grade of natural disasters by using different indicators.

Here A, B, C, D and E are grade 1, grade 2, grade 3, grade 4 and grade 5, respectively. For convenience, we calculate the logarithmic function with 10 as the base, convert the corresponding values of each index into natural numbers, and get the criterion of fuzzy disaster grade division.

The fourth step is to calculate the weight of evaluation index by using analytic hierarchy process. Firstly, a hierarchical structure is established based on the above-mentioned analysis indicators. Then, a judgment matrix is constructed by comparing the nine-level scoring system. Then, the maximum eigenvectors and eigenvectors in the judgment matrix are calculated. According to the calculated results, the consistency test of the constructed judgment matrix is carried out. Finally, after the consistency test is passed, the weight set of the indicators can be obtained.

The fifth step is to calculate the comprehensive evaluation result vector. By choosing the appropriate synthesis operator, the weight set A and membership matrix R are combined to get the fuzzy comprehensive evaluation result vector B of the evaluation object, that is, the membership degree of the evaluated object to each level of fuzzy subset as a whole.

The sixth step is to determine the regional power level. The principle of weighted average comprehensive average is used to determine the regional power level. The principle of this method is that the level of the object is a continuous relative position, using the numerical value 1,2,. N denotes each rank in turn, and these values are called ranks of each rank. Then, the values B J (j = 1,2) in the comprehensive evaluation vector B are used. (n) The ranks of each rank are weighted to get the relative position of the evaluated object.

The principle of weighted average can preserve the original data and process data more intact, avoid the loss of data information, and quantify the grade of the evaluated object, making the evaluation results more intuitive.

2.4 Realization of Reasonable Dispatch of Comprehensive Energy for Cooling, Thermoelectricity and Power

(1) Determining decision variables

Decision variables mainly refer to the generation capacity and power demand level, and there is a certain relationship between them. For areas with low power demand level, the generation capacity is very small, and for areas with high power demand level, the generation capacity is large.

(2) Analysis of objective function

The main factors involved in the objective function are generation capacity and power demand level. With the further development of energy-saving concept, higher requirements are put forward for power supply scheduling. The level of force demand in the objective function determines the amount of electricity generated. The development of objective function in the direction of power dispatching can promote the optimization of power dispatching decision-making model and make Low-carbon Science and technology innovate and develop continuously.

(3) Model constraints

At present, many power enterprises do not pay attention to the classification of power demand levels, resulting in huge waste of power in the actual supply process. In view of this situation, the government has issued an order for the rational distribution of electricity, which has become a constraint for the operation of many large power enterprises. However, in order to achieve the balance between supply and demand levels, it is not enough to rely on the efforts of the government alone. Power enterprises need to improve their own power dispatching mode and decision-making model.

3 Simulation Experiment

In order to prove the effectiveness of the multi-area integrated energy dispatching method for cooling, heating and power based on large data analysis, a simulation experiment is needed. Firstly, an experimental simulation platform is established by using the simulation tool CloudSim. The experimental data are selected from the power supply data of several areas in North China from 2015 to 2019. Now use the method of this study to conduct reasonable dispatch. After the dispatch is completed, the power supply is counted. The results are shown in Table 2 below.

Table 2. Statistical results of power supply

Year	Actual result (KW)	After reasonable dispatch (KW)	Differ (KW)
2015	2536.46	2047.35	489.11
2016	3011.68	2834.87	176.81
2017	3517.21	3247.98	269.23
2018	4563.78	4179.54	384.24
2019	5217.23	4768.95	448.28

From Table 2, it can be seen that the power supply decreases by 489.11 KW, 176.81 KW, 269.23 KW, 384.24 KW and 448.28 KW respectively, with an average decrease of 353.534 KW, which shows the effectiveness of this method.

In order to further verify the reliability of the method in this paper, the time required for the comprehensive energy classification of cooling, heating and power in reference [2, 3] is compared, the results are shown in Fig. 4.

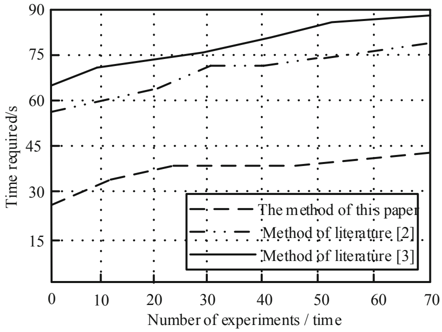

Fig. 4. Comparison of time required for different methods of comprehensive energy classification

It can be seen from Fig. 4 that the time required by the methods in reference [2, 3] in the classification of comprehensive cold, heat and power energy is relatively long, while the time required by the method in this paper is relatively short. The reason is that the dimensionless treatment is carried out in the process of comprehensive energy classification of cooling, heating and power, and the calculation is simple, and the numerical calculation is convenient. The physical equation can be transformed into specific mathematical equation, which is convenient for mathematical processing. The extremum method is used to dimensionless, the original data and processing data are retained completely, the loss of data information is avoided, the grade of the evaluated object is quantified, and the evaluation result is more intuitive.

The main parameters of the optimization algorithm are: the initial population size is 50, the population dimension is 10, the search space is 0–10000 kW, and the maximum number of iterations is 1000. When the inertia weight is large, the global search ability is strong, but the local search ability is poor. Previous studies have shown that the value of inertia weight W should be less than 1 to ensure the local search ability of the algorithm. Therefore, according to experience, the value range of inertia weight W is 0.9 maximum and 0.2 minimum. Learning factors affect the change speed of particles. The existing algorithm research shows that learning factors usually select constants in [0,4], and the number of particles retained in the front end is 8. Equipment capacity configuration corresponding to 8 non inferior schemes is shown in Table 1 (equipment with capacity configuration result of 0 is omitted).

Table 3. Configuration capacity optimization results

Programme	Configure capacity/MW						
	Gas engine	Waste heat boiler	Gas fired boiler	Voltage refrigerator	Absorption refrigerator	Heat storage irrigation	Cold storage tank
1	9.8	13.2	8.9	8.4	11.1	15.6	20.9
2	12.5	17.2	7.7	6.9	14.5	15.3	27.5
3	15.6	21.3	5.5	4.8	18.8	12.6	36.5
4	16.4	22.5	5.2	4.7	18.9	11.5	28.9
5	20.2	25.6	3.3	2.9	21.3	9.2	47.2
6	21.2	28.2	2.7	2.4	24.6	10.5	50.6
7	22.6	29.3	2.3	1.8	25.3	11.2	52.4
8	22.9	30.2	0.0	0.0	28.9	4.6	60.5

It can be seen from Table 3 that electric heating, electric hot water boiler, gas turbine, battery and other equipment are not selected, which indicates that the cost performance of these types of equipment is low under the example price and parameters, and the economic competitiveness is not high. There are heat storage and cold storage devices in each scheme, and the configuration capacity is high, which shows that the configuration of heat storage and cold storage equipment can effectively improve the economy of the comprehensive energy supply system, and has a good value of carbon emission reduction, so it should be given priority. Absorption refrigeration equipment can reduce carbon emission, but its economy is not as good as electric refrigeration equipment. In addition, the comparison of the comprehensive energy supply scheme of this example shows that the larger the capacity of the electric refrigeration equipment is, the higher the overall economic benefit is.

4 Conclusions

In summary, this study explores some problems of power scheduling. At present, regional differences are not taken into account in power system dispatching, which leads to low power utilization rate and serious energy waste. In view of the above situation, a multi-region integrated energy scheduling method based on big data analysis is studied. The simulation results show that this method is effective, solves the problem of unnecessary power consumption and achieves the purpose of energy saving.

The influence of new energy generation forms, including wind power and photovoltaic, on the planning of integrated energy system is not taken into account, and further study is needed. With the deepening of the national energy system reform and the vigorous development of the energy Internet, the integrated energy system is bound to have a larger and larger display stage, and the rational and efficient planning of the integrated energy system will also be the focus of future research.

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