E3S Web of Conferences 256, 02003 (2021) https://doi.org/10.1051/e3sconf/202125602003
PoSEI2021

Description and analysis of typical adjustment scenarios of regional energy system from the perspective of energy network theory

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Abstract. The district energy system has realized the effective consumption of new energy and the cascade utilization of energy, and has been widely used in the continuous and in-depth advancement of China's urbanization process. The district energy system is an organic combination of source-grid-load, and in practical applications, its components are usually in a dynamic change process, which has a certain impact on the matching of supply and demand of the district energy system. This article first puts forward the concept of district energy network, and then describes the typical adjustment scenarios of its energy supply nodes, energy consumption nodes and energy pipe network side respectively, and allocates energy resources of the district energy network according to various typical adjustment scenarios of the district energy network. The impact of the strategy is analysed to provide a reference for the economic construction of the regional energy system and the rational and efficient use of energy.

1Introduction

The energy supply characteristics of distributed energy systems are highly compatible with the energy consumption characteristics of urban areas, and they have been widely used in various urban area energy systems[1]. Most of the existing related research on the resource allocation of regional energy networks[2-7] focuses on the optimization of one-time infrastructure investment plans for regional distributed energy stations and pipeline networks and solved the optimal planning problem of the district energy system under the scenario where the number of load users are unchanged. However, the area of urban areas with various functional buildings continues to expand, and the corresponding regional building energy load also exhibits sequential growth characteristics, which brings about the regional energy network. The redistribution of regional energy network resources under the scenario of dynamic adjustment of energy supply nodes and energy use nodes remains to be further studied. This paper first puts forward the concept of district energy network, and then describes the typical adjustment scenarios of its energy supply nodes, energy consumption nodes and energy pipe network side respectively, and allocates energy resources of the district energy network according to various typical adjustment scenarios of the district energy network. The impact of the strategy is analysed to provide a certain reference for the economic construction of the regional energy system and the rational and efficient use of energy.

2Regional energy network and composition structure

The energy network is composed of input terminals (distributed energy stations), network terminals (various energy transmission pipeline networks) and output terminals (various user loads). Its essence is the "Internet-like" of the energy system. At the end, through various advanced and efficient energy equipment to achieve multi-energy organic complementation and effective on-site consumption of renewable energy, achieve the goal of comprehensive cascade utilization of energy, and solve the problem of low utilization efficiency due to the large fluctuation of renewable energy; On the energy network side, various energy pipe networks can achieve low-energy-consumption and large-capacity transmission in a smaller area. In addition to making energy control more flexible, it also makes it easier to achieve the balance of energy supply and demand; In addition to the diversified energy services provided by energy producers, users on the energy demand side can also access various types of renewable energy utilization equipment such as photovoltaics and solar thermal as well as heat and electricity storage devices according to their actual conditions. It clearly embodies the important characteristics of the open interconnection of the energy network, the free transmission of energy, and the peer-to-peer access. A schematic diagram of a typical regional energy network is shown in figure 1.

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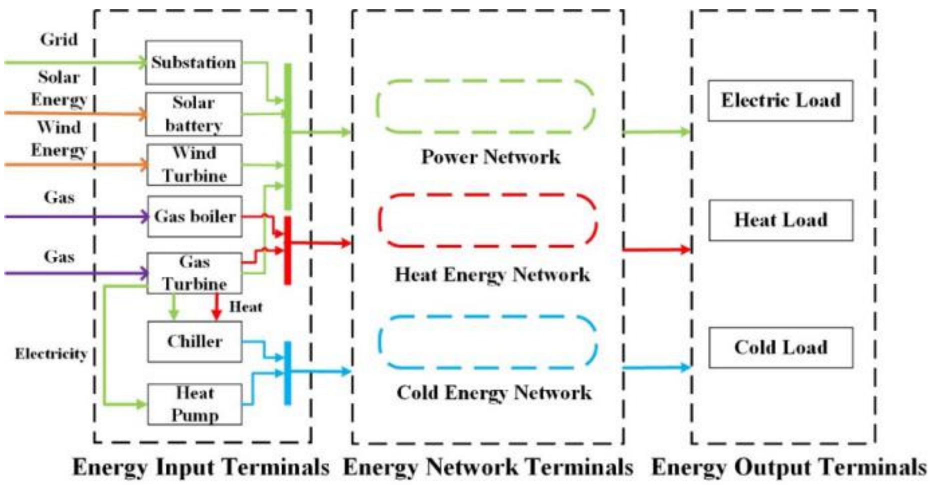

Figure 1. Schematic diagram of a typical regional energy network.

3 Description and analysis of typical scenarios of regional energy network adjustment

Based on the structure and composition of energy network theory, this section will classify and analyse the adjustment of regional energy network based on the above content. The energy supply node adjustment scenarios include changes in the number and location of energy supply nodes, changes in the capacity of each energy supply device in the energy supply node, including energy production equipment, energy storage equipment, and energy coupling equipment; the energy use node adjustment scenario includes the number of energy use nodes Due to the unique load timing characteristics of energy-consuming nodes, the energy-using load will fluctuate; energy pipe network adjustment scenarios include changes in the number and location of energy-supply nodes resulting in changes in the routing topology of the pipe network, changes in the load of energy-using nodes, and management Changes in the traffic topology of the pipe network caused by the failure of the network system.

3.1 Description and analysis of typical scenarios of energy supply node adjustment

From the perspective of energy network theory, the energy supply node as the input end and the energy consumption node as the output end have a very close coupling relationship. From the perspective of supply and demand theory, the adjustment of regional energy consumption nodes means that the regional energy demand side has changed. In order to ensure the matching characteristics of the supply and demand of the energy network, the system must adjust and change the energy supply side accordingly. Therefore, the adjustment of energy supply nodes not only involves changes in the basic attributes of the building such as the number of energy supply nodes and the location of energy supply nodes, but also involves various energy equipment units (including energy production equipment, energy storage equipment and Energy coupling equipment).

3.1.1 Changes in the number and location of energy supply nodes.

Usually, the overall goal is to optimize the overall benefits of the regional energy network system to determine the optimal number and location of energy supply nodes. The selection of the number and location of energy stations should be based on the status quo of regional energy supply and demand, and relevant research should be conducted from the perspective of conducive to the distribution of regional energy network resources. In the study of the change law of the number of energy supply nodes, the characteristics of the regional energy pipe network and energy load should be considered, and based on this, the energy supply range of different energy stations should be reasonably coordinated, the load peak-valley difference rate can be reduced, and the utilization efficiency of energy supply equipment in the energy station should be improved. Achieve the goal of effectively reducing the investment cost of energy station equipment. The location attributes of energy supply nodes should also be studied from the perspective of the overall system. In the research process, regional energy conditions and regional existing conditions should be fully considered, the main factors affecting location selection should be listed, and weighting factors should be assigned to each factor according to the importance of correlation , And calculate the weighted evaluation value of each candidate node, firstly select the combination of candidate sites according to the descending order of the evaluation value, and then select the candidate site based on the construction target of the regional energy network, and finally determine the location of the new energy supply node. Table 1 lists the main factors that affect the choice of energy supply node location.

Table 1. Main factors affecting the choice of energy supply node location.

Classification standard	Natural environmental factors	Socioeconomic factors
Specific contents	Location	National policy
	Water source conditions	Municipal planning
	Wind direction and speed	Environmental requirements
	Geological conditions	Economic benefit
	Available resource distribution	Transportation
	Green landscape impact	Human Resources

3.1.2 Capacity change of energy supply node equipment.

The adjustment of the internal equipment capacity of the energy supply node is also an important factor affecting the supply and demand characteristics of the regional energy network. Taking a regional distributed energy station as an example, the main internal energy supply equipment can be divided into four parts: energy production equipment, energy conversion equipment, energy storage equipment, and energy coupling unit. Energy production equipment is mainly a device that uses renewable energy or consumes natural gas to generate cold, heat, and electricity, such as photovoltaic power generation devices, solar water heating systems, wind generators, etc.; energy conversion equipment realizes cold, heat, electricity, steam, etc. Flexible and efficient conversion of various types of energy, typical representatives such as centrifugal electric refrigerators, lithium bromide absorption refrigerators, heat pump units, gas-fired hot water boilers, etc.; energy storage equipment can effectively store various types of energy and help realize energy use nodes The purpose of side load peak shaving and valley filling is typically represented by various types of energy storage equipment; energy coupling units refer to equipment that generates electricity by consuming natural gas, such as gas turbines and gas internal combustion engines. Since the exhaust steam contains a large amount of waste heat, it can be combined with waste heat. The boiler and the lithium bromide absorption chiller are configured in combination to make reasonable and effective cascade utilization of the remaining heat. There is a certain coupling relationship between the electric energy produced and the heat (cold) energy, so it is called an energy coupling unit. The classification, conversion/coupling relationship and typical equipment list of various energy equipment within a typical energy supply node are shown in table 2.

Table 2. List of typical energy supply equipment inside energy supply node.

Category	Transformation/coupling relationship	Typical equipment
Primary energy-Secondary energy	Light Energy-Electricity	Photovoltaic generator set
	Light-heat	solar water heaters
	Wind Energy-Electricity	Wind power plant
Secondary energy-Secondary energy	Electricity-Heat	Electric hot water boiler, heat pump unit
	Electricity-Cold Energy	Centrifugal electric refrigerator
	Electricity-Gas	P2G device
	Heat-cold	Flue gas hot water type lithium bromide absorption chiller
	Gas-heat	Gas boiler
	Gas-heat, electricity	CHP unit
	Gas-heat, cold, electricity	CCHP unit

The capacity adjustment changes of energy supply node equipment are closely related to the number and location of energy supply nodes, the distribution of energy use nodes and their load characteristics. In the process of formulating regional energy network resource redistribution strategies, from an economic point of view, energy supply Node equipment capacity adjustment should be based on the timing of regional energy consumption planning, considering the number and location of energy supply nodes and the optimal adjustment strategy for the corresponding energy supply range, and based on the load distribution within the energy supply range and the specific characteristics of various loads, combined with energy The pipeline network and energy-consuming nodes simultaneously realize the integrated optimization and adjustment of the regional energy network "source-network-load-storage", and obtain an integrated solution for energy resource distribution/redistribution of the regional energy network.

3.2 Description and analysis of typical scenarios for energy utilization node adjustment

3.2.1 Changes in the number of energy nodes.

In the scenario of adjusting energy use nodes, the number of energy use nodes changes is the most common. my country is in the rapid development stage of urbanization and industrialization, and the regional economy represented by industrial parks and business parks is developing rapidly. The newly-built area includes various typical building types, including factory buildings, office buildings, mid-to-high-end business hotels, mid-to-high-end commercial complexes, etc. Various buildings are gathered in the park, and various loads can be integrated and complemented to become a regional energy network Main energy-consuming nodes in the Various building types and layout schemes in the region are usually determined in the regional construction planning plan. However, due to the time sequence and spatial characteristics of construction, the load of regional energy consumption nodes also shows the characteristics of time series changes. The law of changes in nature and space will cause changes in the characteristics of regional energy networks, including energy supply nodes, energy pipe networks, etc. Therefore, for changes in the number of energy use nodes in a regional energy network, the load characteristics of energy use nodes should first be accurately described On this basis, according to the current status of energy supply nodes and energy pipeline network, reasonable optimization is carried out to ensure the optimal allocation of regional energy network resources.

3.2.2 Changes in load characteristics of energy-consuming nodes.

Regions are becoming the main carriers of urban energy consumption and greenhouse gas emissions. According to the basic characteristics of urbanization development, regional planning emphasizes the balanced and coordinated distribution of various industries. Therefore, the corresponding construction area usually includes various loads, such as living building load, commercial building load, industrial building load, office building load, etc. The load characteristics of different types of buildings are also different, and their quantitative manifestations are the fluctuation characteristics of load under different time scales. Through the analysis of the load characteristics of various types of typical buildings in urban areas, it can be seen that the load characteristics of different types and functions of buildings have great differences over time. The area contains buildings of various types and functions. On the basis of the difference in load time characteristics and the difference in load spatial distribution, the regional load demand presents a more complex and comprehensive characteristic. Therefore, in the process of regional energy network optimization and adjustment and optimal allocation of resources, in addition to the impact on the load of a single energy node The main factors, such as building orientation and structure, envelope performance, climate characteristics, etc., should also consider local area conditions including multiple energy use nodes, such as the geographical location of the local energy supply area and the energy resource endowment of the location As well as the overall load scale and its dynamic change characteristics, the optimal planning, adjustment, and operation and maintenance of the regional energy system can be realized.

3.3 Description and analysis of typical scenarios of energy pipeline network adjustment

The topological structure of the energy pipe network includes the routing topology of the energy pipe network and the flow topology of the energy pipe network. The two influence each other and jointly determine the layout and optimization of the energy pipe network. The adjustment scenarios mainly include the following two categories.

3.3.1 Energy network input and output changes.

The energy pipe network is used to connect the input and output ends of the energy network, and changes in the input and output ends of the energy network will inevitably cause the corresponding adjustment and change of the energy pipe network as the connection link. The topology of the energy network is very complex. The routing topology is the embedded energy pipeline network layout. From the economic point of view, that is, the energy pipeline network investment cost perspective, it is affected by the location of energy supply nodes, the capacity configuration of energy supply equipment and The multiple effects of the division of the energy supply area of the energy supply node. From the perspective of changes in the input and output ends of the energy network, the factors that affect the routing topology of the energy pipeline network include the length of the pipeline network, the timing characteristics of the load of energy-consuming nodes, and the path of its access to the energy pipeline network. The investment and construction cost of energy pipeline network facilities is positively related to the length of the energy pipeline network. The layout of different energy supply nodes and energy use nodes, the characteristics of energy supply capacity of different energy supply nodes, and the load distribution law of energy use nodes affect the road layout based on the region. On the basis of not affecting the stability and reliability of energy supply, the energy supply pipeline network layout should ensure that the length of the energy pipeline network is as short as possible to meet the economic requirements of energy pipeline network construction. The time series characteristics of energy load, such as the seasonal variation of cooling and heating energy loads, directly affect the flow change characteristics of the branch pipe section of the energy pipe network directly connected to the energy load building, thereby further affecting the branch of the energy pipe network. The flow characteristics and distribution rules of the main pipe sections of the energy pipe network connected by the pipe sections affect the flow topology of the entire energy pipe network. The flow difference in each section of the pipe determines the difference in the pipe network diameter, which affects the energy pipe network routing

The layout and adjustment of the topology structure; due to the geospatial characteristics of the energy use nodes, there are one or more energy pipelines around the energy use nodes in different locations and different plots, which serve as the connection direction between the energy use nodes and the energy pipeline network There are also many situations. Different access methods correspond to different routing topologies. Comprehensive consideration of the uncertainty of the growth of energy supply nodes, and different access methods lead to the redundancy of the energy supply pipe network and the phenomenon of pipe sharing. The traffic topology of the regional energy supply pipe network will be adjusted accordingly.

3.3.2 Pipeline failure.

The regional energy pipeline network is connected to the energy supply node and consists of energy supply pipelines, return water pipelines, circulating water pumps, flow valves and other equipment. During the operation of the energy system, pipeline bursts and circulating water pumps, valve equipment, etc. often occur. All kinds of pipeline failures such as damage to pipe network components, including the emergency repairs of the internal equipment and facilities of the energy supply node, when the above situation occurs, it is necessary to close certain valves to isolate the faulty pipe section, and timely repair and replace the faulty equipment. Causes the internal hydraulic characteristics of the energy pipeline network such as the flow distribution and pressure status of the pipeline network, that is, the corresponding change in the flow topology of the energy supply pipeline network. In this case, it is necessary to study a reasonable energy pipeline network flow topology reconstruction Method, the specific requirements are to first search for the necessary measures to isolate the location of the fault, such as closing adjacent valves, and sorting out the temporarily suspended pipe network and the energy supply node information that stopped supplying energy, and then the fault condition To reconstruct the flow topology of the energy pipeline network, and adjust the energy supply node scheduling strategy to ensure that the corresponding loss is minimized.

4Conclusion

This article is mainly based on the theory of energy networks, and describes in detail the typical adjustment scenarios of its various components, namely energy supply nodes, energy consumption nodes, and energy pipeline networks, and analyses the effects of various adjustment scenarios on regional energy network economic resources and energy resources. The corresponding impact of allocation and optimized redistribution lays the foundation for the formulation of a general solution for regional energy network resource optimization and redistribution.

Acknowledgments

The article is supported by National Natural Science Foundation of China (71403162), Science and Technology Innovation Project of Shanghai Science and Technology Committee (18DZ1203304, 19DZ1205604).

References

1. Sun Hongbin, etc. (2020) Energy Internet. SCIENCE PRESS, Beijing.
2. Wang Zhaoqiang, Liu Qingrong, Ruan Yingjun, Wang Hai.(2019) Research and Application of Optimal Layout Method for Station Network Layout in Regional Energy Planning. JOURNAL OF ENGINEERING FOR THERMAL ENERGY AND POWER,34(08):25-30.
3. Liu Hong, Zheng Nan, Ge Shaoyun, Liu Jingyi, Zhang Qunhua, Hu Yaqiu. (2021) Station and Network Coordinated Planning of Integrated Energy Systems Considering Complementation of Load Characteristic. Proceedings of the CSEE, 41(01):52-64+397.
4. Xu Chengsi, Dong Shufeng, Wu Jincheng, Han Rongjie, Shou Ting, Li Jianbin.(2020) Planning of Energy Station and Pipeline Considering Topological Characteristics of Regional Integrated Energy System. Automation of Electric Power Systems, 44(03):74-82.
5. Yi Wenfei, Yu Yongzeng, Zhang Yiwei, Li Zhongcheng, Huang Yongzhang.(2019) p-median Model Based Optimal Planning of Energy Station for Regional Integrated Energy Systems. Automation of Electric Power Systems, 43(04):107-112.
6. Chen Juan, Huang Yuansheng, Lu Bin.(2018) Research on “Stations-Pipelines” Layout and Optimization of Regional Energy Internet. Proceedings of the CSEE, 38(03):675-684.
7. Huang Wei,Liu Wenbin.(2020) Multi-energy Complementary Based Collaborative Optimal Planning of Park Integrated Energy Station-Network. Automation of Electric Power Systems, 44(23):20-28.