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Coordinative Optimal Operation Mode of Regional Energy Internet

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Abstract. Distributed energy has the limitation of "point-to-point" supply. The regional Energy Internet is a multi-dimensional energy network system with energy producers and consumers as nodes, electricity, gas, cold and hot energy networks as links, connecting the production, transmission, distribution, storage and use of energy. The regional Energy Internet realizes the full utilization of distributed energy through the operation mode of multi-source complementary, "energy network load storage" coordination, and optimized control technology.

1. Introduction

In recent years, distributed energy system has become the latest direction of global energy development [1-2]. More and more distributed energy resources (DER) systems are being interconnected to electric power systems throughout the world. It has a huge impact on the traditional mode of energy production, transmission and consumption [3]. As more and more DER systems are applied to multiple types of users such as hospitals, hotels, commerce, and residences, prosumers (producers and consumers) of distributed energy have been formed [4]. Since the production of distributed energy and the end users have obvious fluctuation characteristics, it is difficult to achieve self-sufficiency by relying on existing technologies. The energy efficiency of DERs is low.

Energy Internet provides an idea for the supply and efficient application of distributed energy. A regional Energy Internet is formed by interconnecting multiple adjacent DERs in a certain region. Through the adjustment of the system energy supply mode, the distributed energy system can be kept in an efficient operation state as far as possible. The proposal of the regional Energy Internet has effectively improved the flexibility of the regional energy supply system, and can achieve overall regional energy conservation and efficiency through complementation and interaction. At the same time, the optimization of the entire energy supply network becomes a growing challenge. For this problem, many scholars have done a lot of research. Professor Shah of Imperial College London [5] and Professor Papageorgiou of University College London [6-7] are the main pioneers in this field. They put forward the concept of collaborative optimization of type selection and configuration of distributed energy technology and regional heat supply network topology, and developed decision support systems--SynCity.

Based on the "source-network-load-storage" of power network, this paper studies the collaborative optimal operation mode of regional Energy Internet, which has improved the utilization efficiency of distributed energy.



2. Characteristics of regional Energy Internet

Different from the traditional mode of energy supply, in the regional Energy Internet, energy producers and consumers are integrated into one, which is called prosumers. The regional Energy Internet is a multi-dimensional energy network system with energy producers and consumers as nodes, electricity, gas, cold and hot energy networks as links, connecting energy production, transmission and distribution, storage and use [8].

The regional Energy Internet embodies a three-dimensional energy solution of intercommunication, interaction and mutual assistance as shown in Figure 1. Multiple energy supplies complement each other, multiple energy users share and backup each other, so as to realize the coordination of source, network, load, and storage. Sources include combined cooling heating and power (CCHP) based on fossil energy, solar energy, wind energy, and other renewable energy sources. The network includes electric power network, heating power network, and gas network and so on. Loads include electrical loads, thermal loads, and so on. Energy storage includes electricity, heat, and cold storage. The regional Energy Internet relies on the urban energy network to provide electricity, heat, and cooling for specific areas such as business districts, residential areas, and industrial parks. The cooling load of each individual user in the area is transformed into an electric load by compression refrigeration equipment, and the heating and hot water loads are combined. While each prosumer meets their own consumption, the surplus energy is integrated to other users in the domain through the regional micro-grid and micro-heating network. This make full use of local resources, improve energy efficiency, and ensure energy supply reliability.

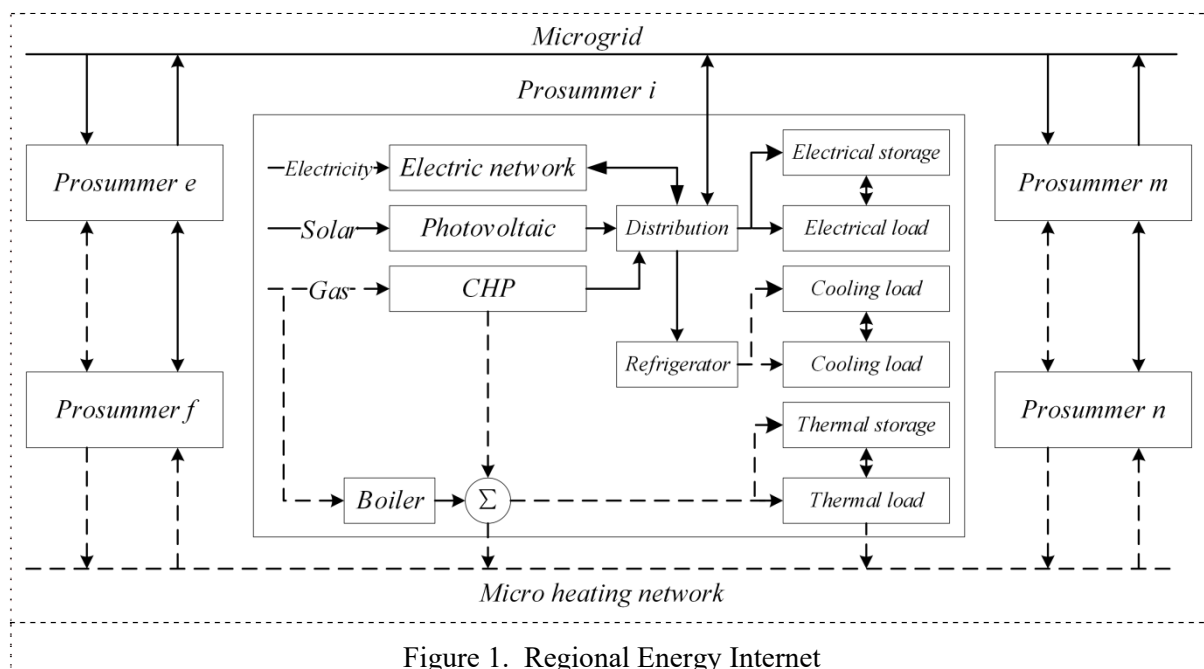


Figure 1. Regional Energy Internet

Energy Internet has the following characteristics:

- (1) The goal of energy Internet is to make full use of renewable energy;
- (2) The unified form and transmission mode of energy Internet is electricity;
- (3) Energy Internet is composed of power generation resource subnet, electricity consumption resource subnet and electricity transmission network;
- (4) Energy Internet adopts the regulation strategy of two-way interaction between power generation and electricity consumption.

3. Coordinative optimal operation mode

3.1. Multi-energy complementary

In the decision-making process of regional Energy Internet optimization, we should not only consider the interdependence of the production capacity, energy exchange and energy consumption of the prosumers, but also consider the interaction of electricity, heat, cold and other multiple energy flows between the producers and consumers. The complementary coordination between the power system, oil system, heating system, natural gas supply system and other energy resources in the Energy Internet, highlighting the "substitutability" between various types of energy, users can not only choose differently among them Energy, you can also freely choose how to use energy resources.

3.2. Source-network-load-storage coordination

As the core and link of the Energy Internet, the "source-network-load-storage" coordination and optimization model of the power system can be more widely used in the entire energy industry, combined with the technology and system of the energy Internet, to form the coordination of the entire energy system Optimize the operating model. The "source-network-load-storage" coordination in the Energy Internet mainly refers to two aspects:

(1) Through a variety of energy conversion technology, information flow and energy flow interaction technology, the development and utilization of energy resources and the coordination between resource transportation network and energy transmission network can be realized;

(2) The demand side management (DSM) will be further expanded into the "comprehensive energy management" in the whole energy field. The role of generalized demand side resources in promoting clean energy consumption and ensuring the safe and stable operation of the system is further enlarged.

3.3. System operation

The system operators collect all the energy consumption information of users and the basic data of the energy supply side through the information communication network, provide the optimized energy consumption scheme for users through the analysis and processing of the cloud information processing system, and guide the users to actively track the clean energy generation output through the reasonable price mechanism and demand side response measures. A reasonable scheduling sequence and output arrangement are designed according to the data information on the power generation side. Combined with the mode of decentralized energy module "self-use, surplus online", the bilateral coordination optimization and two-way adaptive process of the system are realized. It is also necessary to give full play to the link effect of the power system and optimize the operation of other energy modules (such as heating supply, gas supply, etc.).

In the process of system operation, it undertakes the responsibilities of power supply, heat supply, gas supply, power diagnosis, energy scheme optimization design and so on. It also provides energy transmission channels for users in the area covered by energy Internet. Therefore, the revenue of system operators can include electricity charges, transmission and distribution charges, energy information service charges, heating charges and other energy costs.

4. Coordinative optimal control technology

4.1. Technical framework of coordinative optimal Operation Mode

Figure 2 shows the technical architecture of the "source-network-load-storage" coordinative optimal operation mode of regional Energy Internet. The operation of the system requires special technology to control the charging and discharging of distributed generation and energy storage equipment at the micro level, realize the internal self-optimization and self-adaptation of each module at the user end, and improve the controllability of each module. The optimized combination of new energy power generation and traditional fossil energy power generation output, through distributed power generation, energy storage equipment and other technologies, guides users to actively track the power generation

side output. In addition, special information interaction technology is needed to ensure the free flow of information flow between each energy module, collect data information of each module, and perform preliminary classification and processing, so as to meet the user's primary data needs at any time, and input the collected data Cloud information processing part.

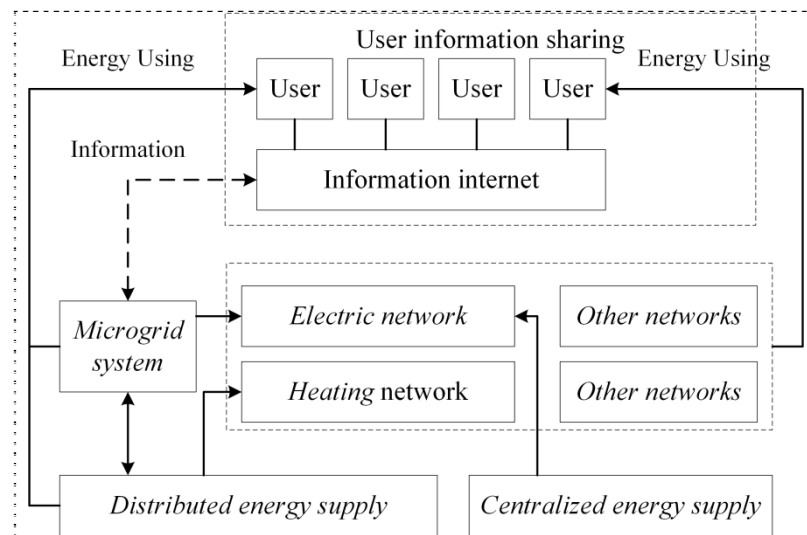


Figure 2. Technology structure of regional Energy Internet

4.2. Multi-energy metering and monitoring technology

Advanced metering infrastructure (AMI) is the foundation of information monitoring technology. And its future research and development will be towards the direction of intelligence, measurement capacity diversification and information interaction. We realize automatic collection, automatic analysis and processing of energy information through wireless sensor technology and telemetry technology. In terms of information interaction technology, in the future, we need to focus on the research and development of information interaction automatic sensing technology, general information interface technology, data cleaning technology, information data compression technology, data information fusion technology, etc., so as to realize the free information exchange and dynamic feedback between users and between users and various energy Internet modules. The main applications of multi-energy measurement monitoring and information interaction technology are as follows:

(1) Information collection and real-time analysis. With the help of Internet technology, "big data" and "cloud computing" technology, the communication module and data management module of AMI system are upgraded to enhance its data throughput processing, data storage capacity and data analysis capacity. Collect users' energy consumption information and other environmental information in real time, conduct preliminary data mining on these basic information, obtain users' energy consumption behavior characteristics, describe users' energy consumption characteristics, etc.

(2) Intelligent electronic device. With the help of the universal access port of the energy Internet, the information interaction platform of various energy equipment in the energy Internet is constructed. With the help of the perfect information analysis and processing ability, combined with the data mining analysis results, the comprehensive energy consumption scheme with multi-energy coordination is provided for users, and the automatic control and automatic optimization coordination of user energy equipment and distributed energy equipment are realized to a certain extent.

4.3. Multi-energy flow complementary control technology

Energy Internet is the coupling of multiple energy networks, which is manifested in the mutual coupling between energy network architectures, and it also includes complementary coordination and

security control between network energy flows. In energy supply, transmission and distribution, the future energy Internet can significantly improve the adaptive ability of power grid through flexible access port, energy router, multi-directional energy automatic configuration technology, energy carrying information technology and so on, realize the flexibility and intellectualization of multi-energy network access port, and reduce the possibility of conflict and blocking of multi-energy cross flow in the network. In case of system failure, it can accelerate the rapid reconfiguration of the network and readjust the distribution and trend of energy flow.

At present, multi-energy flow complementary control technology mainly focuses on control strategy and control technology. The control strategy mainly refers to the optimal dispatch model and control model of multi-type energy generation. The control technology mainly refers to non-traditional control strategies and models based on digital signal processing, including neural network control, predictive control, grid self-healing automatic control technology, Internet remote control technology, fuzzy control technology, access port control technology, and so on.

5. Summary

The access of large-scale renewable energy power generation has a great impact on the power structure and regulation mode of traditional power grid. In the regional Energy Internet, power plays an important role as a bridge between the supply side and the demand side. The "source-network-load-storage" operation mode of power system is extended to energy Internet to form a more extensive regional Energy Internet coordination and optimization mode, which can realize the full utilization of distributed energy.

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