Analysis on Operation Modes of Regional Integrated Energy System based on Interests Exchange Relationship

ZHANG Chen, BAI Cuifen, ZHANG Yue, HAN Xinyang and ZHANG Yan

State Grid Energy Research Institute Co., Ltd., Beijing, China, 102209

zhangchen@sgeri.sgcc.com.cn

Abstract. Regional energy is an energy system solution designed to solve such issues as regional warm, heat, cooling and power supply and satisfy intra-regional energy demands. With the advancement of power marketization reform, newly added transaction subjects will gradually participate in such links as investment, construction and operation of integrated energy system. Considering the exchange relationship of energy, capital and service flows between various interests subjects of integrated energy system, the paper classifies the operation modes of regional integrated energy system according to the combination relationship between power generation, distribution and sales businesses, and also supplies case analysis according to actual demands.

1. Introduction

As early as 1908, International District Energy Association was established to help its members become industrial leaders in terms of the supply of reliable, economic, efficient, environmentally friendly and correct regional energy solutions and promote the improvement of energy efficiency and environment quality by means of such advanced technologies as regional cooling and heating supply and combined heat and power production [1-3]. In the middle of the 20th century, developed countries recognized the economic benefits originating from regional energy, for example, many European countries started to vigorously develop regional heat supply, followed by the energetic development of regional cooling supply and the promotion of combined heat and power production in the 1970s. At the end of the 20th century, while recognizing environment problems resulting from energy consumption, various countries in the world also saw better environment benefits following scientific and rational supply and uses of energy, and then some developed countries started to use energy in an integrated way, thus creating opportunities for the further development of regional energy at the beginning of the 21st century [4-6].

Following the direction of efficiently and fully using local energies, regional energy system, as a beneficial supplement to urban energy supply, is mainly designed to achieve the integrated and efficient use of various local energies and promote the rational absorption and configuration of large-scale extra-regional power by such intelligent power grid technologies as source grid load interaction, multi-energy complementation, power distribution automation. Following the direction of leading energy-saving and interactive energy consumption behaviors, user-side energy system mainly aims to lead users to cultivate such an energy consumption habit featured by electrification and interaction, promote energy saving and improve users’ life quality by such technologies and means as intelligent building, intelligent home, internet of vehicles and demand-side management [7-8]. Analyses and researches on the operation mode of regional integrated energy system are correlated to those on such issues as enterprise operation,
business operation and development strategy, and have large influence on the realization of project construction targets and economy benefits.

2. **Classification on operation modes of regional integrated energy system**

Regional integrated energy system mainly includes three major kinds of operation businesses, namely power generation, distribution and sales, and according to the combination relationship between the three kinds of businesses and actual operation possibilities, regional integrated energy system may adopt the following operation modes, which can be organized by steps and phases, that is what needs to be clearly expounded.

2.1. **Regional integrated energy system operator purely engaging in power sale**

![Energy Generation System](Distributed solar generation, distributed wind generation, small oil generation, garbage generation, gas turbine, energy storage etc.)

![Energy Distribution System](Electricity grid, heat grid etc.)

![Energy Retail System](Cold, heat, electricity, gas etc.)

![Energy Consumption System](Lighting, heating, electricity consumption, gas consumption etc.)

![Energy Market](Energy flow Financial flow Service flow)

**Figure 1. Mode I-Regional integrated energy system operator purely engaging in power sale**

Establish an intra-regional operation entity on regional integrated energy for sales of cooling, heat and power within the region. The operation entity may determine together with local administration of power supply a certain wholesale power price through negotiation or directly sign a contract of direct power purchase for large consumers with power plant based on relevant policies on direct power purchase for large consumers or power transmission and distribution verification. For intra-regional users, it may supply flexible price “package” for their free selection. In essence, the operation mode will not change the assets relationship or construction planning of existing power grid, and neither will the operator of regional integrated energy construct or operate any grid distribution asset, and thus it can serve as a user agent or pure power seller outside. The operator just mentioned can mainly play two roles: first, operating integrated energy, namely implementing self-operation in terms of energy resources under its control, and to be specific, coordinating such distributed resources as PV power, garbage power, gas-fired boiler, peak-shaving boiler, refrigeration station and heat pump and such controllable resources as energy storage system, heat storage system, ice storage air conditioner and electromobility; second, supplying load in an interactive way, namely introducing contractual energy management and demand response service, implementing time-of-use power price and supplying energy services and information value-added service based on bid data, thus providing users with better services.
and reducing their overall energy consumption cost. On the basis of flow-graph as shown in Figure 1, the operation analysis is as follows.

Energy flow: mainly including distributed PV power generation device, small-scale draught fan, small-scale oil-fired generator and energy storage equipment, energy supply system is the main starting point for the production of energy flow of regional integrated energy system, and when the production of energy flow of regional integrated energy system is insufficient, the system also relies on external oil and gas grid for supplement, and then power and heat energy may be configured through regional power and heat grid and supplied to energy consumption system to satisfy such energy consumption demands as lighting, warming and power and gas consumption. In future, energy consumption system will be mainly composed of energy producer and seller and implement active demand-side response, thus making it possible the existence of two-way energy flow between energy configuration system and energy consumption system, and also between energy configuration system and external power grid.

Service flow: two-way service flow exists between external energy market and external power grid, regional energy supply system and also regional energy seller to supply auxiliary services. Besides, two-way service flow also exists between energy consumption system and energy configuration system within regional integrated energy system.

Capital flow: energy consumption system pays energy seller for such energies as cooling, heat, power and gas it purchases, and meanwhile, energy seller also pays corresponding expenses to energy consumption system for demand-side services it supplies. Energy seller on one hand pays energy expenses to energy supply system within regional integrated energy system and configuration expenses to energy configuration system, and on the other hand implements capital transaction with extra-regional energy market. Besides, two-way capital flow also exists between energy market (energy transaction centre of regional network) and external power grid, external oil and gas pipe networks and regional energy supply system.

2.2. Regional integrated energy operator integrating power generation and sales businesses

![Image](image_url)
Based on Mode I, we can organize an energy supplier integrating power generation and sales businesses through incorporating intra-regional energy supply system into the operation scope of energy supplier and constructing regional energy centre.

As shown in Figure 2. The energy, capital and service flows of the operation mode are all similar with those of Mode I, and the difference of the two modes lies in that the energy supply plan of energy supply system is not issued directly by energy supplier, instead it is executed by regional integrated energy operator after implementing self-decision in combination with such factors as intra-regional load demands and peak and off-peak power prices and having the plan submitted to energy configuration plan for safety verification. The mode may change neither the assets relationship or construction planning of existing energy configuration system nor the grid connection position of energy supply device.

2.3. Regional integrated energy operator integrating power distribution and sales businesses

Based on Mode I, this mode allows energy supplier to operate intra-regional existing and newly added energy configuration systems. Being similar with Mode I in terms of energy, capital and service flows, as shown in Figure 3, the mode is featured by the basic formation of a physical “wholesales area” and the existence of clear measurement gateway and settlement relationship between energy supply system and energy configuration system.

2.4. Regional integrated energy operator integrating power generation, distribution and sales businesses

As shown in Figure 4, in this mode, regional integrated energy operator can simultaneously operate energy supply, configuration and sales systems and implement integrated dispatching and control over intra-regional energy production and configuration and user-side resources.
3. Case study

3.1. Regional integrated energy operator integrating distribution and sales businesses

The operation mode integrating power distribution and sales can strengthen the relationship with users through power distribution network and support the implementation of power sales business, and it can also improve assets use efficiency though integrating power distribution and use, thus making assets more economical. Many foreign power distribution networks were privately invested and constructed, such as those in such European countries as France and German, especially in German, where most power distribution network assets are privately owned owing to the wave of privatization occurred at the end of 1990s. Afterwards, with the opening of power sales market, many power companies integrating distribution and sales businesses which possess power distribution network assets emerged, and compared with other power sales companies, these companies can acquire benefits from both power distribution network business and power sales business. Considering foreign practices and domestic trial implementation situations, the operation mode integrating distribution and sales will become one of the common operation modes for incremental power distribution in the future.

In this scenario, the operator will carry out businesses in a certain industrial park, and in this case, the internal supply system of the industrial park only includes distributed power supply, small-scale oil-fired generator, gas-fired unit and other power generation equipment, and power distribution and sales company only operate power and heat energy, which means that gas resource necessary for the industrial park still needs to be acquired from external gas network.
According to the flow direction relationship of capital flow shown in Figure 5, operators have mainly two profiting modes in terms of their core power distribution and sales businesses: first, operators can supply basic energies to users in the industrial park to acquire energy consumption expenses from users, which is reflected as power and heat benefits in this case; second, it is easier for power distribution and sales companies with power distribution resources to take the lead in the market and become minimum-guarantee power sales company, and thus acquire a large quantity of user resource, thanks to which such companies can implement such value-added services regarding power sales as energy efficiency management and demand-side response using their power distribution resources according to users’ demands. It can be seen from capital flow direction that the operators just mentioned typically purchase power from the internal energy supply system of the industrial park, and in case that internal energy supply is insufficient, they will implement power transaction through external energy market.

Meanwhile, the operators under this mode are supposed to sacrifice more and bear more risks, as they should firstly invest more capital to construct or transform power distribution network, and they also need professionals and advanced management technologies for daily operation and maintenance of power distribution network. For example, the development of renewable energies will inevitably produce large influence on the planning scheme of power distribution network, especially distributed renewable energies, as most of power generation equipment using such energies need to access to power distribution network, thus making it a necessity the expansion and transformation of power distribution network, which undoubtedly forces power distribution and sales companies to invest more capital, and second, they also bear policy risks, as current power transmission and distribution price verification methods may change, which makes it more uncertain the income of such companies integrating distribution and sales businesses.

3.2. Regional integrated energy operator integrating power generation, distribution and sales businesses

For historical reasons, some enterprises with conventional power supply also posses power distribution system to secure their production, and when the market is open, such enterprises are more willing to participate in market businesses, and thus can easily become integrated energy operators integrating the distribution and sales of conventional power supply. Taking enterprises possessing domestic power plant...
as an example, under the promotion of reform, some large users possessing domestic power plants or CHP units intend to establish power distribution and sales company to supply power to other enterprises and acquire the support of local government. Such large-scale enterprises and industrial parks with domestic power plants are more likely to become operators integrating power generation, distribution and sales businesses when implementing integrated energy businesses in the future, which is taken as the case for analysis in this section, and corresponding operation mode is shown as follows.

According to the relationship of capital flow direction shown in the Figure 6 and the case mentioned above, we can conclude that operators integrating power generation, distribution and sales businesses can supply users with energy resources using their own energy systems without paying power purchase expenses additionally, and when domestic energy supply is insufficient, they can acquire additional energy resources from external market. Besides, both their capital and service flowing directions at the side of energy consumption are the same with those of operators integrating distribution and sales businesses, and they all can acquire benefits through supplying basic energy supply services and energy value-added services to users.

Seeing from the actual development power distribution network in China, some large-scale energy enterprises with domestic power plants have already acquired power sales license, and they can further participate in power market transactions and compete with intra-regional power grid enterprises in the future. In addition to providing power supply service to self-owned enterprises, they can also provide similar power consumption services to intra-regional industry and commerce and also residents. Such companies typically possess natural energy supply resources, relatively mature and complete power generation and distribution system and a batch of stable energy users, thus having great advantages in creating regional integrated energy system within their operation scope.

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