



Market Mechanism Design to Stimulate the Value of Energy Internet

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Abstract. In recent years, with the deep integration of energy revolution and digital revolution, the power grid is accelerating its transformation and upgrading to Energy Internet with a higher level of intelligence and interaction, stronger resource allocation and value creation capabilities. The construction and operation of electricity market is an important starting point for realizing the value creation of the Energy Internet, and the construction and development of the Energy Internet will also bring about fundamental changes in the field of electricity market. This paper researches and designs an electricity market mechanism that meets the value creation needs of Energy Internet. The trading mechanism for emerging entities, innovative electricity retail model and innovative electricity trading service platform are provided to stimulate the value creation capabilities of Energy Internet.

Keywords: Electricity market · Energy Internet · Emerging Entities · Commodity Value · Added Value

1 Introduction

In the traditional power system, the technical and economic characteristics of electricity commodities and the network characteristics of the power grid determine that there is a close interaction between power grid and electricity market. Power grid is the physical basis of electricity market, at the same time, the development of electricity market has also driven the development of power grid. With the transformation and upgrading of traditional power grid to Energy Internet, the interaction between electricity market and Energy Internet will become closer and the benefits will be more prominent. Through the benign interaction and mutual empowerment of electricity market and Energy Internet, it will help to fully tap the potential of resources, enhance market vitality, accelerate the transformation of traditional businesses and promote scientific development and value promotion.

In terms of emerging entities' participation in electricity market under Energy Internet, literature [1] established the models of energy storage, controllable load and gas turbine in virtual power plants, and proposed the bidding strategy for virtual power plants to participate in the energy and rotating reserve market. Literature [2] proposed

a modulus for flexible load to participate in real-time equilibrium market, and quantitatively evaluated the economic value of price based demand side response. Literature [3] studied the participation of energy storage aggregators in electricity market transactions based on cooperative games. Literature [4] proposed a collaborative mechanism of distributed energy under market mechanism, designed an energy system platform to support massive new energy consumption and tap flexible resources on demand side. This paper analyzes the value realization method of Energy Internet, and designs an electricity market mechanisms to stimulate the value of Energy Internet. Three key mechanisms are provided to realize the value creation.

2 Value Realization Method of Energy Internet

The design of the market mechanism that stimulates the value of the Energy Internet should take value discovery as a link, and focus on building a system that can further subdivide the types of power transactions, mobilize the enthusiasm of multiple subjects of source, network, load and storage, support flexible and intelligent energy consumption needs, and build a comprehensive market value realization system for services and data information. Specifically include the following aspects:

2.1 Electricity Trading Market (Commodity Value Realization - Trading System Construction)

- (1) **Economic and social value:** Relying on Energy Internet to complete the production, exchange and allocation of electric power commodities to meet the economic and social electricity demand, it is the basic function and mechanism of electric power market [5]. This function is mainly realized through electric energy market.
- (2) **Safety/flexibility value:** The power system is an instantaneously balanced system. Therefore, power products are not only provide electricity volume, but need to provide electricity capacity at the same time, so as to ensure the stable operation of the power system. With the construction of “dual carbon” and new power systems, the anti-peaking characteristics and volatility of renewable energy put forward extremely high requirements for the flexibility of power system operation, and the ability to guarantee power balance has increased significantly. It is necessary to establish a reasonable market mechanism to reflect values such as flexibility, security and reliability capabilities.
- (3) **Green low-carbon value:** Since pure energy market cannot fully reflect the green attributes of renewable energy, other policy measures are needed to support its development and reflect its green external value. By improving renewable energy quota trading, exploring the development of green power trading and carbon trading markets, etc., we will promote the formation of a market-oriented green energy consumption and circulation system, and help clean and low-carbon energy transformation.

2.2 Innovation Service Market (Realization of Added Value - Business Model and Technology Innovation)

- (1) **Customer service value:** Under the Energy Internet, with the rapid development of distributed power sources, multiple loads and energy storage, many user-side subjects have dual attributes of power generation and consumption, and a large number of “prosumers” have emerged, and users will have conditions for extensive and in-depth participation in the interaction of electricity consumption and production, the identity and scale of both transaction parties are no longer restricted, and the coexistence and competition of multiple internet-based trading platforms will become the norm. In this environment, in addition to traditional electricity commodity transactions, it is necessary to focus on creating user-centered market value. On the one hand, to meet the diversified energy demand of users, and carry out diversified power trading value-added services; on the other hand, to inductively change the consumption habits of users and provide innovative trading goods and services, thereby creating new value for the entire energy system.
- (2) **Data application value:** In the Energy Internet era, data-centric business models will play an important role. During the operation of the electricity market, a large amount of electricity production, transmission, consumption, and transaction data are involved. Based on these data information, value-added services such as data mining, operation monitoring, behavior analysis, risk management and control, credit evaluation, and auxiliary decision-making can be carried out to help market players, operating agencies and regulatory agencies find problems, optimize operations, improve efficiency, and support the “Internet+ electricity transaction” service concept to realize the transfer, exchange and effective use of data value.

3 Design Ideas of Electricity Market Mechanisms to Stimulate the Value of Energy Internet

To adapt to changes in the operating characteristics of the Energy Internet and new power systems, take value discovery as the link, take the realization of commodity value and added value as the starting point, and focus on innovation in terms of architecture design, transaction mechanism, service model, and technical support (“One System Architecture + Three Key Mechanisms”), build a comprehensive market value realization system with multiple value creation functions, mobilizing the enthusiasm of various entities of source, network, load and storage, supporting user-side flexibility, intelligent energy consumption needs, and comprehensively reflecting value of various resources, value-added services and data information, as shown in Fig. 1.

System architecture: Improve the full-form market system architecture that stimulates the value of the Energy Internet, and create a green, low-carbon, safe and reliable electricity market. On the basis of traditional electric energy transactions, optimize the types of auxiliary service transactions, establish a capacity cost recovery mechanism, carry out innovative green power transactions, coordinate the construction of electricity-carbon market, and gradually establish a complete electricity market system covering multiple types of transactions.

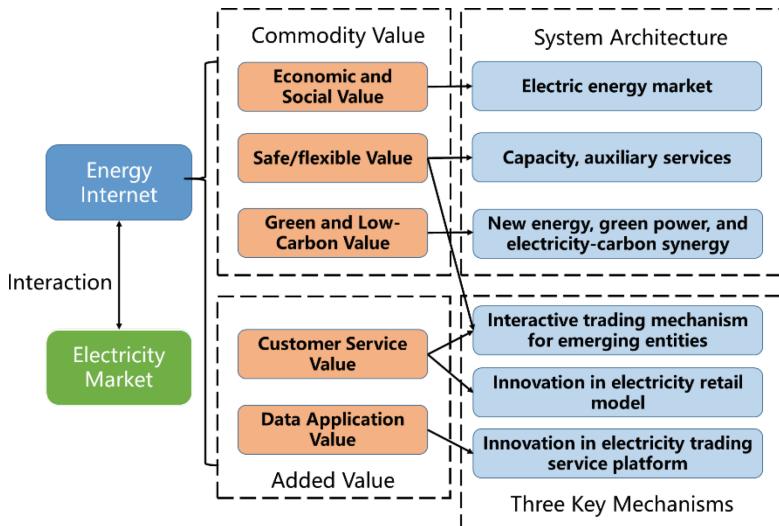


Fig. 1. Design of Market Mechanism to Stimulate the Value of Energy Internet

Key mechanism 1: Build a market transaction organization mechanism that meets the transaction needs of various entities of source, network, load and storage, and create a flexible and interactive electricity market. Using market mechanism to guide centralized energy, distributed energy, flexible loads, energy storage, virtual power plants, new energy vehicles and other entities to participate in and interact extensively, realize the interoperability and flexible conversion of various energy sources, and empower traditional businesses. It will give birth to new formats and provide support for various entities to expand space and stimulate vitality.

Key mechanism 2: Strengthen cultivation of entities on sales side and innovation of service models, cultivate electricity market ecosystem with open competition situation. Guided by the actual needs of sales side market entities, improve retail market trading mechanism, use platforms and other technical means to provide customized and standardized service products and high-quality transaction settlement services to electricity sales companies and retail users, and strengthen the risk prevention and control of retail market; innovate and establish new electricity trading models such as electricity group buying, Taobao energy trading, and intelligent aggregation trading, to effectively improve the convenience and sense of gain for retail market players to participate in the market, and increase market activity; build connection and coordination between retail and wholesale markets, and strengthen prices signal transduction and synergy.

Key mechanism 3: Improve electricity trading service and technical support platform, and promote the construction of an intelligent, efficient, standardized and transparent market. Enrich and improve the functions and application scenarios of the electricity trading service platform, and provide a variety of convenient and efficient services. Actively explore the value of trading big data assets, and explore the digital infrastructure of market operations. Expand the application of new technologies such as

block-chain and big data in retail transactions, credit evaluation, compliance management, market services and other fields, integrate trading platform operation channels, build an “e-transaction” service platform, and create an authoritative traffic portal for electricity market.

4 Key Points of Market Mechanism Design to Stimulate the Value of Energy Internet

4.1 Interactive Trading Mechanism for Emerging Entities

Relying solely on traditional resources on generation side is not enough to support the construction of new energy system, and it is urgent to further improve the market mechanism that taps the flexible response capabilities of all links in the system. The construction of the Energy Internet has created favorable conditions for various emerging entities such as virtual power plants, load aggregators, distributed photovoltaics, and energy storage to participate in the market. Emerging market entities can gradually participate in ancillary service markets, power spot transactions, medium and long-term transactions, capacity markets, financial derivatives market and carbon market, etc.

Taking the participation of virtual power plants (VPP) in the peak shaving auxiliary service market as an example, the costs of virtual power plants mainly include fixed investment costs and peak shaving costs. The peak shaving cost consists of two parts, one is compensation cost of resources such as internal interruptible load, and the other is peak shaving cost of gas turbine.

$$A^{inv} = C^{INV} \frac{i(1+i)^n}{(1+i)^n - 1} \quad (1)$$

$$C_t = \sum_{M_l=1}^K (C_t^{i,re,k} + C_t^{i,sh,k} + C_t^{i,tra,k} + C_t^{i,DG,k}) + C_t^{GT} \quad (2)$$

$$C_t^{GT} = a(P_t^{GT})^2 + bP_t^{GT} + c \quad (3)$$

where C^{INV} is the initial investment cost of technical equipment of the virtual power plant; A^{inv} is the average annual investment cost of virtual power plant; n is the operation period of virtual power plant after the investment in relevant equipment technology; i is the investment interest rate; $C_t^{i,re,k}$, $C_t^{i,sh,k}$, $C_t^{i,tra,k}$, $C_t^{i,DG,k}$ are the compensation costs of VPP internal resources participating in peak shaving at time t ; C_t^{GT} is the peak shaving cost of gas turbine at time t ; P_t^{GT} is the output of gas turbine at time t ; a , b and c are gas turbine operating cost coefficients respectively.

The peak shaving benefit of VPP at time t is as follows:

$$R_{as,t} = Q_{t,up} \cdot v_{t,up} + Q_{t,down} \cdot v_{t,down} + Q_{t,re} \cdot v_{t,re} \quad (4)$$

where $Q_{t,up}$, $Q_{t,down}$, $Q_{t,re}$ are the output of up regulation, down regulation and rotating reserve auxiliary services provided by VPP respectively. $v_{t,up}$, $v_{t,down}$, $v_{t,re}$ refer to the

prices of up regulation, down regulation, and rotating reserve services provided by VPP respectively.

The electricity sales revenue of VPP at time t is as follows:

$$R_{es,t} = \sum_{s \in S} (Q_{t,sale,s} v_{t,sale,s}) - Q_{t,e,buy} v_{t,e,buy} \quad (5)$$

where $Q_{t,sale,s}$ is the electricity volume sold by VPP to users s at time t ; $v_{t,sale,s}$ is the selling price of VPP at time t ; $Q_{t,e,buy}$, $v_{t,e,buy}$ refer to the electricity purchased by VPP from the power grid at time t .

To sum up, the benefits of VPP are:

$$\pi_{vpp} = \sum_{t=1}^{8760} (R_{as,t} + R_{es,t} - C_t) - A^{inv} \quad (6)$$

The VPP takes the maximum expected net income as the decision-making goal to optimize the output of internal units.

$$MaxF = E(\pi_{vpp}) \quad (7)$$

4.2 Innovation in Electricity Retail Model

Under the Energy Internet, through the deep integration of advanced information communication technology and electricity trading platform, it can provide customers with personalized customized services and efficient information, making it possible to “meet directly” for power generation and user side, reducing intermediate links and transaction costs.

- (1) **B2B transaction mode:** Through the information provided by the platform, the buyer and seller can carry out various types of flexible energy transactions, for example, the large users or electricity sellers can directly carry out B2B transactions with power plants (online OTC transactions), or directly participate in centralized bidding transactions organized by the electricity trading platform.
- (2) **B2C transaction mode:** The platform can provide business similar to “power Taobao”, allowing power producers and sellers to “set up stalls” on the platform to sell different energy packages, which is convenient for small and medium-sized users to choose. The platform can also rely on its own resources or technical advantages to carry out “self-operated” agent power purchase and sales business, the platform can act as an electricity sales company (load aggregator) selling power to small and medium-sized users.
- (3) **C2C transaction mode:** The platform can support C2C based electricity trade between small and medium-sized users, carry out transaction of electricity contracts, etc., which liberalize energy trading like e-commerce.
- (4) **C2B transaction mode:** The platform can also support users to publish their personalized energy demand, and the electricity sales companies can “delist” to provide them with corresponding customized packages, so as to achieve personalized C2B services.

4.3 Innovation in Electricity Trading Service Platform

Electricity trading platform under Energy Internet is positioned as a power trading and value-added service platform that is oriented to multiple market entities in wholesale and retail market, and where sources, networks, loads and storage are widely involved in interactions, as shown in Fig. 2. The main functions and typical application scenarios are as follows:

- (1) **Wholesale market electricity trading organization:** including registration management, trading organization, transaction settlement, contract management, information disclosure, credit evaluation, etc.
- (2) **Retail market power trading organization:** including organizing power users to directly trade on the platform, supporting power users to choose power sales companies as agents for transactions, supporting power grid enterprises to act as agents for power purchase transactions, direct transactions between emerging entities and power users, and developing decentralized transactions, etc.
- (3) **Carrying out diversified power supply services:** including traditional power supply services, engineering services, power supply services for residential and agricultural users, guaranteed power supply services, etc.
- (4) **Providing various value-added services:** including energy efficiency management, multi-energy supply, information services, big data services, energy financial services, etc.

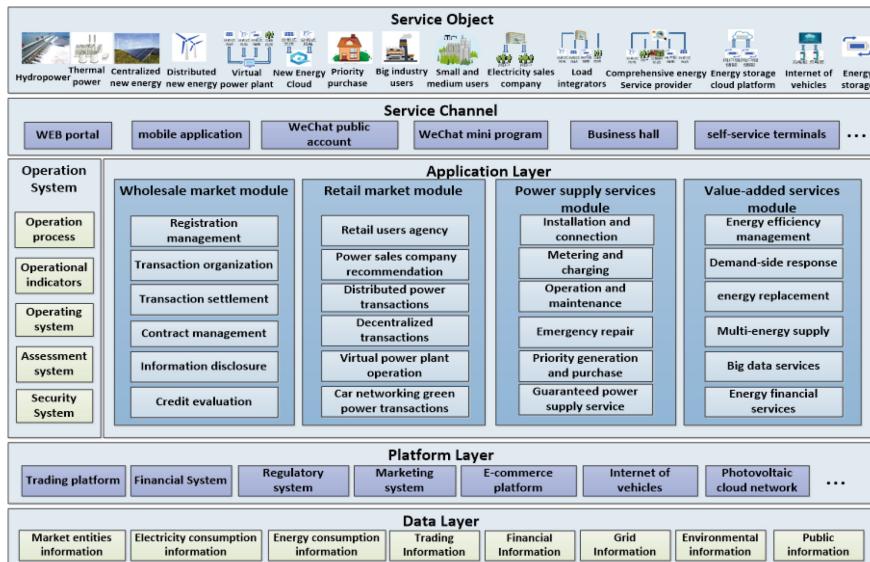


Fig. 2. Overall architecture of electricity trading service platform based on Energy Internet

5 Conclusion

Adapt to changes of Energy Internet and new power systems, based on the interactive relationship between the value creation of the Energy Internet and electricity market, with value discovery as the link, focusing on innovations in architecture design, transaction mechanism, service model and technical support, etc. (“One System Architecture + Three Key Mechanisms”), this paper builds a comprehensive market value realization system. The trading mechanism for emerging entities, innovative electricity retail model and innovative electricity trading service platform are provided to stimulate the value creation capabilities of Energy Internet.

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