Research on the Framework of the New Urban Energy Internet Demonstration Project

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Abstract. Energy is the main driving force of economic development and social progress, and the relationship between its production and supply directly determines the destiny of the country. As to the new urban Energy Internet demonstration project, the characteristics and elements of the new urban Energy Internet are analyzed in this paper, and then the overall framework and information integration framework of the new urban Energy Internet demonstration project is proposed. Finally the overall framework and functional requirements of Energy Internet comprehensive management and service platform and the perception layer equipment are proposed, which can provide technical support and framework guidance for the development of new urban Energy Internet business.

1. Introduction

China is experiencing the largest urbanization process, in which the problems such as high energy resource consumption and insufficient clean energy utilization are serious [1]. The comprehensive energy efficiency level is far lower than that of developed countries such as Europe and the United States. Urban development needs to enter the stage of improving quality, and it is urgent to build a new energy supply system and market model to provide clean and efficient energy guarantees for green and low-carbon urbanization.

"Internet +" smart energy (Energy Internet) is a new form of energy industry development that deeply integrates the Internet and energy production, transmission, storage, consumption, and energy markets with the characteristics of multi-energy coordination and open transactions. And it provides an important support for promoting the development of new urbanization and the transformation of clean energy structure [2].

2. Overview of Energy Internet Demonstration Project

At present, the research on Energy Internet in the domestic and overseas is not limited to the theoretical aspect, and relevant integrated energy demonstration projects have been built. Overseas integrated energy demonstration projects include the Mad River pilot project in the United States, the Yellowknife Town demonstration project in Canada, ELECTRA demonstration project and E-DeMa project in the European Union and Kashiwa-no-ha Smart City project in Japan [3-4]. Domestic integrated energy demonstration projects include Shanghai Disney Resort, Tianjin china-singapore eco-city demonstration project, Tianjin Binhai Internet Smart Energy Management System project, Tongli New Energy Town project, and Liandao Energy Integrated Service Demonstration Island.
project [3]. Although a lot of research and practice on the integrated energy system have been done, a complete research system of the Energy Internet demonstration project has not been formed, especially there is no Energy Internet demonstration project framework under the background of the new urbanization development.

The new urban Energy Internet has the following characteristics: firstly, new energy and renewable energy will be vigorously developed. Secondly, there are a large number of diversified distributed energy systems. Thirdly, the new towns will establish a regional Energy Internet system with "source-source" complementarity and "source-load" interaction. Fourthly, the new towns will emphasize more on the deep integration and sharing of information technology and energy technology. Fifthly, a diversified development trend will be showed in the new urban energy markets and service entities.

3. Framework of the New Urban Energy Internet Demonstration Project

Compared with the traditional energy development path, the new urban Energy Internet is composed of the source-network-load-storage energy system and users, coordinated control devices, users’ energy systems, information platform and data, policy standards and other elements. Among them, energy system usually refers to an integrated energy system or a multi-energy complementary energy system. The Energy Internet realizes the interconnection and mutual aid of these energy systems, and improves energy efficiency while rationalizing the energy supply structure. And the coordinated control devices installed in the energy system are key equipment to realize the interconnection, complementing and coordinated operation of the energy system, which can realize source-load interaction and the unification of information flow, value flow and energy flow, and provide equipment support for the coordinated operation of the Energy Internet. Users’ energy systems and equipment are the basic elements of source-load interaction and innovative business models of energy market. The information platform and energy data provide technical data support for integrated energy service providers to build Energy Internet business. And the standards and specifications include data protocols, security and other technical guarantees.

3.1. Overall Architecture

The overall architecture of the Energy Internet demonstration project includes four parts: sensing layer, network layer, platform layer and application layer. The access and integrated management of wind, light, gas, geothermal, biomass and other forms of energy can be realized through the coordinated control device. The Energy Internet comprehensive management and service platform can provide technical support for energy service providers to carry out related business in new urban Energy Internet.

3.1.1. Sensing layer

It contains source-end devices, load-end devices, energy storage devices, information devices, acquisition devices, etc. such as PV inverters, energy storage converters, non-intrusive devices, sensors, etc. And it also contains new technology equipment, such as multi-energy information interaction devices, AC/DC bidirectional converters, multi-port power conversion devices, plug-and-play energy storage converters, etc., as well as distributed energy systems, such as PV systems, energy storage systems, combined cooling, heating and power system (CCHP), ground-source heat pump system (GSHP), etc. The platform realizes data acquisition and control of multiple types of energy through these devices or systems, and provides data support for multi-energy energy planning, operation optimization, energy trading, and technology economic evaluation and energy operation and maintenance, and provides technical support for the integration of energy flow, value flow, information flow, and business flow in the energy system.

3.1.2. Network layer

It mainly contains power information network, power information 4G private network, mobile APN network, etc. The platform conducts data interaction with power dispatching automation system,
distribution automation system, electric energy data acquire system and other systems through the power information network, and collect energy data through 4G private network, and collect other kinds of energy data through mobile APN network (non-power information 4G private network coverage area) with deploying safety protection devices.

3.1.3. Platform layer
Energy Internet integrated management and service platform mainly includes support platform and six major subsystems (integrated energy basic application subsystem, energy planning subsystem, operation optimization subsystem, distributed energy transaction subsystem, Energy Internet technology and economic evaluation subsystem, and integrated energy operation and maintenance subsystem), and achieves full business coverage in the field of integrated energy services. The platform comprehensively considers the actual situation of the energy distribution and construction characteristics of new towns, the characteristics of urban users' energy consumption, seasonal effects, etc., and designs interface standards and security standards of data collection and transmission, system integration, information models, data fusion, information interaction and other aspects. And then the overall framework of new urban Energy Internet integrated management and service platform system architecture is built.

3.1.4. Application layer
The Energy Internet comprehensive management and service platform is a shared, open, and interactive integrated energy service platform with diversified service objects, including power supply companies, power distribution companies, energy operators, and government agencies, Energy users, social users. The Energy Internet comprehensive management and service platform improves the quality of integrated energy services by providing differentiated integrated energy services for different users. For example, it provides the whole control of energy operation indicators for government agencies, provides multi-energy operation optimization, management and control services, technical and economic evaluation services, etc., for power supply companies and energy operators, provides energy trading services for power distribution companies, energy users and energy operators, provides energy operation and maintenance services for energy operators and energy users, and provides energy efficiency analysis services for various users.

3.2. Integrated Architecture
The construction of Energy Internet is a huge information project which needs to integrate and summarize various energy data. Its information sources are diverse and clearly differentiated, mainly including power grid data information, heating network data information, cooling network data information, gas network data information, distributed energy data information, user-side data information, etc.

The demonstration project realizes data integration and interaction based on the data fusion technology, and clarifies the application integration specifications of subsystems based on the integrated platform, the integrated data model that supports multiple energy types and multi-service applications, high reliability, high real-time and high efficiency data transmission security standards, and plug-and-play device interface standards and other related standards.

Based on the comprehensive consideration of various information sources and acquisition networks, the specific methods of information integration are mainly divided into three categories: power business system data, external energy system data, and energy data collected directly.

3.2.1. Power business system data
Power business system data mainly includes data of Distribution automation system (DAS), Power production management system (PMS), Energy management system (EMS), Supervisory control and data acquisition system (SCADA) including grid operation data, distributed energy data, user-side load data and equipment asset information, etc.
This part of the data collection is carried out in the power management information area. The dispatch automation system and distribution automation system collect data through its publishing system in the power management information area. A firewall is installed between the systems using its standard interface E file or webservice interface for data collection.

3.2.2. External energy system data
External energy system data mainly refers to data of combined cooling, heating and power (CCHP) system, PV system, energy storage system, wind power system, ground-source heat pump (GSHP) system, micro-grid system, user energy center, pipe network system, etc. Operating information, equipment status, equipment parameters, data statistics, and pipe network equipment information of external energy system is mainly collected.

This part of the data collection is carried out through the power 4G private network or mobile APN network, and a data security access area is deployed between the power information network and the public network to ensure system data security. The collection method is IEC104 protocol, file transmission or special convention.

3.2.3. Energy data collected directly
Energy data collected directly refers to data information of various energy sources and related equipment. It mainly includes operation information and equipment status of photovoltaic devices, energy storage devices, wind power devices, charging pile facilities, user-side non-intrusive devices, AC/DC bidirectional converters, multi-port power conversion devices, plug-and-play energy storage
converters, phase change heat storage devices and various sensors. This part of the data collection is carried out through the power 4G private network or mobile APN network, through the multi-energy information interaction device and other intelligent gateways, using IEC61969/61970, 61850, Modbus, MQTT protocol, 376.1 protocol, etc. In view of data security considerations, a data security access area is deployed between power information network and the public network to ensure system data security. The details of overall framework are shown in Figure 1.

4. Energy Internet comprehensive management and service platform

4.1. Platform Architecture

The new urban Energy Internet comprehensive management and service platform is the core management and control center of the entire demonstration project. The platform has basic modules such as message bus, service bus, real-time library, history library, authority management, user management, resource management, configuration management, graphic primitives, alarms, etc. The system integrates six application subsystems including basic energy management and control subsystem, energy planning and design subsystem, multi-energy flow energy management subsystem, distributed energy trading subsystem, comprehensive evaluation subsystem, and comprehensive energy operation and maintenance subsystem, and also provides basic functions such as data acquisition and system display. The overall framework of the new urban Energy Internet comprehensive management and service platform is shown in Figure 2.

![Figure 2. Overall framework of the new urban Energy Internet comprehensive management and service platform.](image-url)

The new urban Energy Internet comprehensive management and service platform adopts the construction idea of “one area, one system, and intelligent services”. Each application shares a set of hardware environment. It adopts an integrated software platform to conduct integrated model management and maintenance of various heterogeneous energy sources (wind, light, gas and heat), pipeline networks, equipment, energy stations and users, and business processes. It collects data of each sub-item based on a unified information interaction standard and information security
framework, and exchanges data with external systems such as power dispatch automation system, power consumption information collection system, local system of energy station, etc. And all original data and reprocessed data constitutes a full-service data center.

Relying on the standardized public services, integrated model center and all business data center provided by the platform, applications including energy monitoring, energy measurement, energy efficiency diagnosis, optimization scheduling, transaction settlement, operation and maintenance control, planning and design, comprehensive evaluation and so on are constructed to achieve the integrated operation of the entire process of comprehensive energy pre-planning/online operation/post-assessment management, to realize the widespread access and joint scheduling of different energy sources including electricity, water, gas, heat and cold, and to realize the efficient connection of the various energy links of multi-energy flow source-grid-load-storage and all business links of electricity distribution company operation and distribution, which will help the demonstration zone improve the deployment efficiency and comprehensive energy efficiency, build a multi-energy coordinated supply and conversion consumption system, explore new energy trading models, provide better service for various users, and accelerate the transformation into a regional multi-energy supplier and a multi-energy supply platform operator.

4.2. Hardware architecture

According to the information security requirements of the State Grid, the core data of the power grid operation cannot be placed in the Internet area, and several core applications such as energy planning, operation optimization, technical and economic evaluation of the new urban Energy Internet comprehensive management and service platform require the core data of power grid operation. Therefore, the platform adopts a joint deployment method in the management information area and the Internet area.

The database server, application server, interface server, etc. are deployed in the management information area, while the data collection server is deployed in the Internet area, and data collection is performed through the secure access area; and the information publishing server is deployed in the two major areas. And release of full data is implemented in the management information area, and release of process data and non-core data is implemented in the Internet area with a safe manner.

5. Multi-energy information interaction device

5.1. Supporting role

The multi-energy information interaction device is an information interaction device that supports multiple communications and multiple protocols, and has edge computing function. Through different communication media and communication protocols, it realizes the aggregation, centralized processing, on-site analysis and processing of energy terminal data such as distributed PV, combined cooling, heating and power (CCHP), wind power, ground-source heat pump (GSHP), energy storage, phase change heat storage and other energy terminal data in the demonstration area. At the same time, it satisfies the data interaction with Energy Internet comprehensive management and service platform, and realizes the information interconnection and comprehensive energy control of the demonstration area.

5.2. Main functions

5.2.1. Multi-energy information acquisition and control functions of different energy stations

The multi-energy information interaction device can collect data from distributed PV, wind power, geothermal, CCHP, energy storage and other energy sources in the demonstration area, and receive the operation control strategy issued by the Energy Internet comprehensive management and service platform. After receiving the control strategy of the superior, the device interacts with the back-end monitoring system of each energy entity to implement the superior strategy.
1) Monitoring of distributed power generation system (PV, wind power)
   The device monitors the real-time operation information, fault and alarm information of wind power generation and PV generation systems. The current power, daily power, total power, wind speed, operating status, etc. of wind power generation can be monitored, and real-time power curves can be displayed. The current power, daily power, total power, light irradiance, PV panel temperature, DC terminal voltage, current, etc. of PV power generation system can be monitored, and real-time power curves can be displayed.

2) Monitoring of energy storage system
   The device monitors three parts of the energy storage system including energy storage bidirectional converter, battery management system and battery monitoring module. The real-time operating information of energy storage batteries including single-cell battery voltage, internal resistance, estimated performance, SOC and alarm information is comprehensively monitored, and various statistics and analysis on energy storage can be conducted. The battery of a specific branch can be diagnosed and maintained separately through the monitoring system.

3) Monitoring of combined cooling, heating and power (CCHP) station
   The device monitors the operating data information of gas turbines, boilers, refrigeration and heating devices of CCHP station, and performs early warnings and alarms according to threshold settings, and analyzes the operating data.

4) Monitoring of load
   The device monitors and counts the internal load of new energy, and provides basis for power balance control of new energy. When constructing new energy, all loads can be classified. During operation, these loads can be classified and monitored, and the balance of the whole new energy active load and reactive load can be achieved with the local load controller.

5) Environmental monitoring
   Integrated environmental monitoring function mainly includes total radiation, total scattering, wind speed, wind direction, outdoor temperature and humidity, air pressure and other information.

6) Control of distributed generation operation mode
   Distributed power generation mainly has two working states: running and stopping. The operation control of distributed generation mainly controls the operation state of distributed power generation based on the internal operation of the main grid and new energy sources.

7) Control of energy storage operation mode
   The device controls the starting, setting, grid-connected and off-grid status of the energy storage system. In the grid-connected operation mode, the energy storage system can be controlled by constant power charging and discharging, constant current charging and discharging, and constant voltage charging and discharging. In the off-grid operation mode, the voltage and frequency setting values of the v/f operation of the energy storage system can be set.

8) Strategy generation and issuance
   According to the current load, the control strategy of distributed power supply can be adjusted and issued to the device for execution. According to the plan data issued by Energy Internet comprehensive management and service platform, the operation of the distributed power supply can be adjusted and sent to the device for execution.

9) Operation control of micro-grid
   The device can receive the start/stop instructions of micro-grid from comprehensive management and service platform, and complete the start/stop operations of devices and switches in the micro-grid. The micro-grid can be started in the grid-connected state, and off-grid start (black start) function is also supported.

   The device can receive the power adjustment instructions of microgrid from comprehensive management and service platform. According to the configuration of micro-grid equipment, the output of each distributed power generation unit is adjusted to realize power control in different modes.

5.2.2. Support the mainstream communication protocol of heterogeneous energy management system
The device can realize the edge-side visual management of primary equipment, sensors, network nodes, communication links, and edge computing algorithms, so that users can interact with them. Downlink communication supports heterogeneous access including terminal sensors and plug-and-play devices.

Uplink communication interface supports communication protocols such as IEC61850, IEC60870-101/103/104, and IEC61850 supports MMS and Goose protocols. Downlink communication interface supports IEC61850, IEC60870-101/103/104, Modbus, DNP3.0 and other communication protocols, and IEC61850 supports MMS and Goose protocols. The communication protocols can be dynamically expanded. The communication protocols are relatively isolated from communication scenes and modes. The communication protocols focus on the analysis of communication messages, making communication protocols simple, reliable and easy to debug. The communication interfaces can use Ethernet Internet, RS485/RS232, GPRS, etc. The number of accessible terminals is greater than 128.

5.2.3. Function of actively adjusting the operation strategy and coordinating the operation with the platform

The device has the function of local coordination and optimization for various newly connected energy sources to meet the maximum and optimal use of energy. At the same time, it also receives and executes the overall energy scheduling strategy of Energy Internet comprehensive management and service platform to realize power control, power quality monitoring and analysis, economic operation analysis, etc.

6. Conclusions

As to the new urban Energy Internet demonstration project, the characteristics and elements of the new urban Energy Internet are analyzed, and the overall framework of the new urban Energy Internet demonstration project is proposed to provide framework guidance for the development of the new urban Energy Internet business. The information integration framework of the new urban Energy Internet demonstration project is proposed to provide information support for the new urban Energy Internet business. The overall structure of Energy Internet comprehensive management and service platform is proposed to realize the efficient connection of the energy links of the multi-energy flow source network and the various business links of the integrated energy service providers. According to the application requirements of the perception layer of the new urban Energy Internet, the function requirements of perception layer of common coordination control device are proposed to realize the information interconnection and comprehensive energy management and control in the demonstration area.

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