Technical Architecture of Energy Internet Experimental Platform in Smart Grid

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Abstract. Facing the comprehensive complex challenges of the Energy Internet practice, such as the imperfect design of the technical structure system, incomplete standard system and synergetic control between multi-energy supplement, this paper first explains the importance of building an energy internet experiment platform for studying core technologies of the Energy Internet and then proposes a loosely coupled technical architecture, finally analyses the core technologies for realizing the experimental platform of Energy Internet to show the feasibility and necessity to implement it.

1. Introduction
The integrated applications of smart power electronics technology, information technology and intelligent management technology are popular. Energy Internet, using Internet thinking, synthesizes a large amount of distributed energy harvesting devices, storage devices and new power network nodes which consist of various types of load, in order to achieve bidirectional exchange and sharing of energy flow[1].

However, during the practice the Energy Internet structure is not perfect. Waste of wind, water and light, long-distance transmission loss etc., a series of issues needs to be studied. It is very necessary to develop an experimental information system that can be used repeatedly, supports multi-users, and has strong expansibility to provide research on simulation, testing and verification for Energy Internet in order to improve the reliability of power electronics system.

2. Brief Descriptions of Energy Internet

2.1. Main forms of Energy Internet
Focusing on the research topics of energy Internet, various research institutions, enterprises and industries focus their topics on Energy Internet, and further describe the concept, structure and development direction of energy Internet. Five kinds of main form of energy internet are formed and introduced[2,3,4]:

1) Energy Internet: Based on the network architecture and concept of the Internet, the Energy network model formed backbone network (large power grid), local area network (micro network) and network connection equipment. Energy Internet mainly focuses on the research of energy network structure.

2) Internet of Energy: Information-driven energy supply and demand intelligent scheduling, focusing on the impact of information technology on the intelligence of Internet energy dispatch.
3) Internet Energy: Internet Energy focuses on the deep integration of connected information technology and energy network. Through the bi-directional communication between energy net and internet, the energy flow can be flexibly and intelligently guided by users' needs.

4) Multi-Energy Internet: Focus on the multi-energy complementarity of energy, that is, to achieve complementary energy supply, such as power system, thermal system and gas system in the energy Internet, to achieve the optimal energy efficiency of the energy system.

5) Global Energy Internet: UHV grid is the backbone network, focusing on the wide interconnection of power grids in various countries and the global allocation and coordinated development of energy resources.

Although the focus and scope of energy Internet research are different, the goal of building energy Internet is common. It aims to promote energy consumption to high growth, high efficiency, low input, low energy consumption and low pollution.

2.2. Main characteristics of Energy Internet

Summarized from the research contents of various countries, the components of the energy Internet are divided into six major areas: energy supply, energy consumption, energy transmission, energy management, energy storage, and information and communication technologies supporting the above five aspects. It forms the five characteristics of the energy Internet [5,6,7]:

1) Renewable: Focus on the proportion of renewable energy supply, reduce energy pollution, and promote the transformation of traditional energy networks to the energy Internet.

2) Distributed: According to the decentralized characteristics of renewable energy, build coordinated control and scheduling of energy supply sources, and promote micro-energy networks to form a node of the energy Internet and improve the security of energy networks.

3) Interconnectivity: Through the connection of each local micro-energy network and the intelligent energy dispatching, the energy exchange balance between the local micro-network and the global energy Internet is realized.

4) Openness: The energy Internet should be a peer-to-peer, flat-energy, two-way energy sharing network that enables “plug and play” of energy and various energy devices.

5) Intelligent: The generation, transmission, conversion and use of energy in the energy Internet should have certain intelligence.

However, at present, there is no universal software experiment platform for the study of energy Internet characteristics at home and abroad. Traditional power system software such as PSCAD, NETMAC, PowerWorld, etc. cannot effectively meet the energy Internet integrity and system due to problems such as system closure and insufficient function expansion. Sexual and interdisciplinary panoramic experimental research demonstration.

2.3. Main purposes of building an experimental Information system

According to the characteristics, basic status and challenges of the energy Internet, we propose to build an energy Internet Experimental System. The Energy Internet Experimental System is dedicated to the integration of information and communication technology, energy Internet simulation technology and modern control theory, to adapt to the new requirements of energy Internet development. It is a loosely coupled energy Internet experiment based on service-oriented system architecture. Research an open platform to support the dynamic integration of hardware devices such as grid equipment terminals, natural gas network terminals, and thermal energy network terminals, algorithm implementation and service deployment, and support energy Internet in energy supply, energy consumption, energy transmission, energy management, energy storage, Model modeling, scene construction and scene simulation for multi-energy complementation, offline analysis and calculation of energy Internet scenarios, distributed online collaborative simulation and digital physics hybrid simulation, energy Internet architecture, related standard protocols, distributed energy systems.

The energy Internet experimental platform is built to provide an open energy Internet experimental research platform to strengthen the construction of data model standards for energy Internet in energy
supply, energy transmission, energy storage, energy consumption, energy management, and multi-energy complementation, to verify the algorithms on market operation algorithms, to research on hardware terminal equipment information integration, and multi-energy collaborative control, to accelerate the construction of energy Internet in practice.

3. Architecture of Energy Internet Experiment System

3.1. Functional requirements

In order to meet the cross-professional and interdisciplinary experimental simulation verification requirements of the energy Internet, the energy Internet platform needs to have the following requirements:

1) Support cross-professional, multi-dimensional, multi-functional model modeling needs

The energy Internet platform involves the comprehensive utilization of energy sources such as electricity, gas, oil, and new energy. The multi-disciplinary equipment involved needs to support various energy supply equipment, energy transmission equipment, energy metering equipment, and energy communication equipment in the energy Internet. Equipment model construction, data standard construction, through model construction, strengthen the standardization of various equipment standards, realize the information exchange compatibility of various devices of energy Internet, and effectively improve the system integration between multi-energy complementarity.

2) Support an open platform with high flexibility and scalability

The energy Internet experiment platform needs to support the collection and processing of power grids, natural gas grids, thermal power grids, power generation equipment, energy storage equipment, and various types of load information. In energy operations, it is necessary to support the construction of power market structures, transaction models, and market scheduling scenarios. Therefore, the energy Internet experimental platform allows user model modeling, scene modeling, scene simulation, algorithm dynamic construction and expansion, allowing users to encapsulate data, models, and algorithm components in the research field according to technical standards, and has service-oriented dynamic deployment. To support open access to all users.

3) Support digital physics hybrid simulation of key equipment

The energy Internet experiment platform needs to have the integration of power network, natural gas network, thermal network, power generation equipment, energy storage equipment terminal and platform, meet the requirements of carrying out the hybrid simulation of energy Internet digital physics, and support the function and performance scenario test and verification of energy terminal equipment. It satisfies the construction and experimental verification research of the grid operation scenario, realizes the remote control of the hardware equipment of the energy internet experiment platform, and provides support for the physical hybrid simulation and collaborative control of the energy Internet.

3.2. Architecture of the Platform

According to the functional requirements of Energy Internet, The Energy Internet Experimental System meets the construction of typical scenarios for energy and load energy flows, business flows, and related models in the energy Internet. Provide economical, safe, reliable, convenient and efficient energy service simulation to enhance the construction of energy-friendly and user-friendly energy Internet projects.

The Integrated Energy Internet Experimental System comprehensively considers energy Internet in terms of energy supply, energy transmission, energy management, energy storage, energy consumption, system integration, etc. in model modeling, scenario construction, scene simulation energy efficiency management, and market according to different levels of user needs. In terms of operational requirements, it is proposed to build an open software and hardware energy Internet experiment platform to guide the construction of energy Internet. The overall architecture of the energy Internet experiment system is shown in Figure. 1:
The overall architecture of the energy Internet experiment platform follows the cloud computing architecture model and is divided into three layers: infrastructure layer, platform layer and application layer:

1) The infrastructure layer: the infrastructure layer mainly includes four parts: IT hardware and software infrastructure, power network equipment, natural gas network equipment, thermal network equipment and related equipment control terminals. The IT software infrastructure provides basic guarantee for the operation of the energy Internet platform, and the equipment control terminal. Provide a unified standard specification for software control hardware, collect low-end device operation data through wired/wireless mode, and provide support for subsequent data processing and application.

2) The platform layer: The platform layer adopts multi-level and parallel-expandable service cluster technology to provide a high-performance operation platform for joint research and large-scale application of various units. The main contents include model data center, algorithm implementation center, hardware integration center, algorithm service/hardware gateway service, service management, management center, service registration center. The model data center is mainly used to store the metadata of modeling software construction and the calculation data in the simulation process; the algorithm implementation center is mainly used for scene calculation algorithms of energy internet, such as energy trading algorithm, power flow algorithm, energy scheduling algorithm, etc. Multi-language development; the hardware integration center realizes the unified interface of the device terminal gateway through the adaptive development of the terminal device communication protocol, and reduces the complexity of the secondary integration development of the terminal device. Algorithm service/hardware gateway service conforms to the idea of SOA, and provides service-encapsulation of algorithms and hardware gateway interfaces, so as to realize the loosely coupled architecture of the system platform and meet the dynamic and flexible expansion requirements of the system. The service management center and the service registration center mainly provide an operation management environment for the service software, enabling the platform to support grid computing, stream computing, and enhancing the scalability of the platform.

3) Application layer: for various simulation scenarios such as power system and power market operation, the energy internet experiment platform provides model modeling, scene modeling, scene simulation, energy efficiency comprehensive analysis for scenes and power trading operation status analysis for open users. Capacity building, providing users with standard data description specification standards, scenario operation algorithms, development application standards, supporting offline simulation, online collaborative simulation, digital physics hybrid simulation and other simulation forms, providing flexible simulation research and verification for energy Internet.

4. Core technologies

4.1. Integration Technologies
The underlying hardware devices of the Energy Internet Experiment Platform mainly connect intelligent sensing, data collection, and smart metering devices such as thermal networks, gas networks, and power grids through intelligent terminal devices to achieve docking with the experimental platform and complete information exchange. With the development of communication technology, hardware integration has formed relevant technical standards. The mainstream technologies are KNX, ZigBee, Modbus, M-Bus and related Linux drivers.

KNX is the unified protocol standard of the Konnex Association. It is the only global residential and building control standard. The Konnex Association is a joint association of three European bus protocols EIB, BatiBus and EHSA. The KNX protocol is a solution for home and building automation. It is based on the development of computer technology, provides the basis for building automation and is based on the development of devices such as twisted pair, radio frequency, power line or IP/Ethernet to realize the decoupling between the device manufacturer and the application system, and simplify the secondary development of the application of the device.

The ZigBee protocol is based on the IEEE802.15.4 standard. It effectively supports effective communication between ZigBee devices from different vendors. It has strong interoperability and has various security assurance measures such as encryption algorithm, data integrity and authentication technology. Large capacity, good scalability, etc.

ModBus is a proposed industrial communication system solution that supports programmable control of intelligent terminals. At present, it is widely used in the working network. Some PLCs, DCS and smart meters in the power system also use the Modbus protocol as the basic standard communication protocol.

M-Bus is the instrument bus communication protocol, mainly to meet the needs of network systems and remote meter reading, and to support the remote terminal data collection requirements of water, gas, electricity and other metering equipment.

Through the integration of the above commonly used general protocol standards, the integrated gateway of the energy interconnection experiment platform is developed to realize the open, shared and effective integration of the underlying hardware devices of the energy internet experiment platform, which facilitates the application development of the upper layer.

4.2. High-performance micro-service architecture technology

Energy Internet is a comprehensive system with high complexity and wide coverage. It involves multi-dimensional technical systems such as energy domain, system domain and working domain. Energy domain includes wind energy, solar energy, main network energy and energy storage. Different types and forms of energy types, the system domain is embodied in different functional abstract layers such as device layer, communication layer, information layer, application layer and transaction layer. The working domain involves human activities such as planning, production, scheduling, management, and market area. In order to enable the energy Internet platform to support various simulation scenarios, the energy networking experimental platform adopts a service-oriented architecture idea, supports model design in various fields, supports typical algorithm service applications, improves resource reusability, and provides development efficiency. To avoid repetitive construction.

In order to make the energy internet experiment platform integrate with D5000 platform technology efficiently, the energy internet experiment platform adopts Ice Grid micro-service architecture technology, which is based on the development of RPC framework, has very good computing performance and distributed expansion capability, and supports computing node dynamics. Extended, support service access load balancing, support for stream computing and message publishing. At the same time, through the integration of Spring-boot, application development based on REST protocol is provided for application layer application software.

4.3. High Concurrency, Highly Reliable Cache Technology

The scenario simulation of the Energy Internet Experiment Platform involves a large amount of computational data and supports multi-user use. The Energy Internet Experiment Platform provides a high-performance cache architecture to meet the complexity of the energy Internet model data, large
amount of scenario algorithm calculation, and between modules. The characteristics of frequent interaction, the energy Internet experiment platform cache architecture adopts combination architecture mode with Nginx and Redis. Nginx is mainly used for traffic distribution and hotspot data storage, Redis mainly does the platform full data cache, but the user's request is not cached in Nginx. The data, the user's request will be automatically directed to the Redis cache, through the Redis cluster architecture, to achieve horizontal expansion of the cache, thereby improving the high-concurrency, high-availability of the energy Internet experimental platform, and improving the energy Internet platform business application system Running speed.

5. Conclusions
This paper firstly clarifies the main forms, characteristics, and components of the Energy Internet, and secondly points out the necessity and business requirements for the construction of the Energy Internet Experimental Research Platform. Finally, it proposes the framework and key technologies of the Energy Internet Experimental Platform. To generalize, effective reference and clear construction direction are introduced for the construction of an Energy Internet Experiment Platform. On account of the deficiencies of the existing research, the follow-up research will focus on the innovation of the business model and the development of platform visualization and unified integration of equipment communication protocols.

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