Research on Standard System Architecture of Metrology Technology for Energy Interconnection*

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Abstract: Based on the strategic goal of building the world-class energy internet enterprise in China, combined with the important content of widespread power internet of things, it analyzed the new demand and development direction of the metrology technology under the new situation. A kind of measurement standard architecture that can support the energy internet need is proposed based on the existing measurement system architecture, the contents of relevant standards that need to be revised or added in each layer of the system (device layer, communication layer, interoperability layer, security layer, system layer) are specifically studied, which provides guidance for the promotion and revision work of relevant standards, promotes industrial technological innovation, and supports industrial optimization and upgrading.

1. Introduction
At present, the world is in a new round of technological revolution and industrial transformation led by the Internet, the guidelines on promoting internet plus smart energy development issued by the national development and reform commission, national energy administration and ministry of industry and information technology, which clarifies the development mode of internet plus smart (hereinafter referred to as the energy internet), and points out that the internet concept, advanced information technology and the energy industry should be deeply integrated[1]. The new technologies, models and new formats are emerging, and the reform of electric power is being further promoted with the rapid development of energy internet. In 2019, the two sessions of the State Grid Corporation has made the comprehensive promotion of the construction of “three types and two networks”, speeding up the strategic deployment of building the world-class energy internet enterprise, at the same time, it is pointed out that the construction of widespread power internet of things is the core task of implementing the strategic goal of “three types, two networks and world-class” and the construction outline has been formed[2].

It has analyzed the new demand and development direction of the metrology technology under the new situation, a kind of the measurement standard architecture has been studied and established that can support the energy internet need.
2. New metering business and technology development demand analysis under the energy interconnection new situation

2.1. The energy interconnection business construction

Energy interconnection is a new form of energy industry development with deep integration of Internet and energy production, transmission, storage, consumption and energy markets, which mainly is to build an intelligent system for energy production and consumption, a multi-energy collaborative integrated energy network, and an information communication infrastructure that is coordinated with the energy system, create an open and shared energy internet ecosystem, establish a new energy market trading system and commercial operation platform, develop new models and new formats for distributed energy, energy storage and electric vehicle applications, smart energy and value-added services, green energy flexible trading energy big data service applications[3]. Facing building the world-class energy internet enterprise, the company takes the widespread power internet of things as the basic framework of information sharing network in the field of energy interconnection power field, that refers specifically to the following in order to implement core tasks of strategic objectives:

1. Improve the holographic sensing ability around all aspects of the power system, realize energy collection, transmission, conversion, utilization of equipment in each link, customer's state full perception and full penetration of services.

2. Improve ubiquitous connection capability, realizing instant connection of internal equipment, users and data, and realize full-time ubiquitous connection between power grid and upstream and downstream enterprises and customers.

3. Improve the ability of opening and sharing: better play a leading role, create greater opportunities for the development of all industries and more market entities, and achieve value creation.

4. Improve business innovation capability: promote the deep integration of "two networks" and data integration, and enhance management innovation, business innovation and business innovation capability.

Energy interconnection construction constructs a new generation of information communication system with internet thinking, at the same time needs strong and reliable energy infrastructure as support. Strong smart grid and ubiquitous power internet of things jointly constitute the basic framework of energy interconnection from two dimensions of physics and information. Strong smart grid supports safe and stable transmission of energy flow in power system, widespread power internet of things is to achieve end collection and collection processing of power system information flow. The strong smart grid carrying power flow and the widespread power internet of things carrying data flow complement each other and develop together to form a "three-tier-one" energy interconnection of energy flow, business flow and data flow [4].

2.2. Measurement new demand business analysis of energy interconnection

The related measurement demand need to focus on supporting new or changing business scenarios around the construction of intelligent integrated energy services, based on the changes of the new energy interconnection industry, that has shifted from traditional product-centered service mode to diversified energy production and consumption service mode to satisfy end-users[5], the new demand business of measurement includes:

1. Public utility energy service: the interaction of multi-energy automatic collection and copying and use of the energy, water, gas supply and heating for public utilities, realize public real-time energy interconnection and sharing, energy efficiency analysis, and build public utilities unified service platform combined with Internet platform technology.

2. Distributed energy service: Distributed energy is the foundation and development focus of the energy interconnection, that can be operated independently and realize grid-connected access under the different requirements of users, whose characteristic are multiple sources, multiple points and close interaction with the demand side [6]. These related technologies are the focus of research of
distributed energy, for example including the metering, access, "plug and play" and "two-way transmission" of consumer facilities.

(3) Wisdom energy new mode: Establish energy and energy efficiency integrated services for smart homes, intelligent buildings, smart communities and smart factories, realize intelligent customization, active push and resource optimization combination of multiple energy sources, promote user energy efficiency and efficiency, and provide personalized energy efficiency management and energy saving services focus on customer service mode.

(4) Vehicle Networking service: Intelligent vehicle networking is an interconnection platform between vehicle and power grid, vehicle and energy, charging piles have been used as data exchange hubs for electric vehicles, users and energy with the large-scale popularization and application of electric vehicles, that is the important entrance for the widespread power internet of things on the user side. It is necessary to develop intelligent charging and discharging mode of vehicle network cooperation to promote the two-way interaction of energy and information between electric vehicle and smart grid.

(5) Electric energy substitution (energy saving and emission reduction): Increase the proportion of electric energy in terminal energy consumption, improve energy efficiency and promote energy conservation and emission reduction. Urban rail transit and railway electrification mileage have increased rapidly, and port shore power, airport operation vehicle oil reform and other have fully promoted. Electrical energy has gradually replaced coal and non-commodity energy, oil and natural gas, which promotes continuous improvement in the level of electrical energy substitution in industry, construction and living field [7].

2.3. Metering technology development need of energy interconnection
Energy interconnection metering fully applies modern technologies such as big data, internet of things, artificial intelligence, mobile internet, edge computing, and virtual simulation from the technical level to realize measurement, perception, acquisition, and human-computer interaction of power system business, whose development needs to support:

(1) Measuring the real-time measurement, ubiquitous connection and perception of measuring new demand business (public utility energy, distributed energy, smart energy, vehicle networking, electric energy substitution).

(2) Data collection of massive user-side data, power system edge data and smart energy new technologies and new business in addition to basic power production business key node data and big data analysis applications.

(3) Energy conversion, information exchange and interconnection.

(4) The function expansion and architecture upgrade of next generation metering equipment to support the new energy interconnection business.

(5) It requires higher power supply reliability, which involves high security and reliability requirements of metering equipment, acquisition equipment, system and the detection technology with society's dependence on electricity.

3. Study on standard system architecture of metrology technology for energy interconnection

3.1. Current measurement standard system analysis
The current power metering technology standard system is subdivided according to equipment standards, safety protection standards, information interaction standards and measurement collection standards, the main structure and related standards are shown in Figure 1. The content covers the technical standards of the smart energy meter series, the technical standards of the electricity information collection system, the field operation and the quality control related standards. The technical standard structure has been relatively perfect, mainly used to support the current business model and technical level. However, limited to the power industry, the relevant measurement
technology support for new changes and demands involving multi-energy integration across industries is insufficient.

3.2. **Standard system architecture design of metrology technology for energy interconnection**

Design a kind of measurement standard architecture that can support the energy internet need based on the existing measurement system architecture and in line with the principles of systematicness, inheritance and expansibility [8], the architecture is shown in Figure 2, which include device layer, communication layer, interoperability layer, security layer and system layer, each layer adds some additional or revised series of standards for energy interconnection demand.

![Fig.1 Current measurement system architecture](image-url)
3.3. Analysis on the change of measurement Standards of energy interconnection

For the measurement standards architecture of energy interconnection, the key descriptions of changes in standards that need to be added or revised are as follows [9]:

3.3.1. Metering equipment layer

(1) Establish the technical specification for smart meter to meet the demand of multi-energy measurement: formulate relevant standards for the diversified interactive service functions of smart meters to meet increasing demand for interconnection between suppliers and users with the more and more frequent interaction between power grid and users'energy flow, information flow and business flow.

(2) Technical specification for high reliability of smart meters: for higher reliability of power supply, the relevant standards for high reliability meter and metrology technology, standards, inspection and testing technology, certification and accreditation based on the building of NQI (National Quality Infrastructure) need to be revised.

(3) Technical specification for smart meter with operating system and smart meter of internet of things: as the most basic sensor equipment of smart meter, it is necessary to further design the relevant specifications of smart meter with operating system and smart meter of internet of things to adapt to the new business scenario of energy interconnection.

(4) Standards for intelligent sensors: Distributed sensing technology based on optical fiber and reliable transmission technology of sensing information will be the focus of standard-making work, there are also standards for wide-area coverage, high reliability and anti-strong electromagnetic interference intelligent sensor network constructed power grid information physical fusion system, standards for identification and location technology of intelligent sensors based on integration of network-aware transmission.
(5) Electric energy measurement standards for electric vehicle charging facilities: relevant contents such as harmonic measurement and elimination, DC electric energy measurement, orderly charging and discharging need to be supplemented.

(6) Establishment and improvement of inspection and testing standards for charging and replacement facilities: there are differences between the existing series standards for charging equipment of electric vehicles testing and the requirements for new equipment, it is necessary to supplement the test conditions, rules, methods of high-power charging equipment and wireless charging equipment in the new standards.

(7) New intelligent energy equipment: It is necessary to prepare relevant standards for the operational energy-saving performance level indicators of new equipment and new systems.

(8) Distributed power plug and play standard: The distributed power plug-and-play standard mainly solves the compatibility problem of convenient and fast access of distributed power.

(9) Microgrid metering equipment: User-side microgrid metering demand is getting more and more forced with the rapid development of microgrids and the integration of multiple distributed power sources, relevant technical specifications such as metering requirements, two-way interaction, and energy efficiency management devices under different modes of microgrid support shall be formulated.

(10) Non-invasive energy efficiency analysis and accident monitoring equipment standards: It is necessary to formulate relevant standards such as functional technical requirements, safety protection requirements, and inspection technical specifications of relevant equipment.

(11) Metering device password application and information security standards: It is necessary to formulate the communication technology standards including low-voltage power line broadband carrier communication, dual-mode communication, high-speed power wireless private network and multi-integrated data acquisition technology, information security encryption and password application and other technical standards.

(12) Electric energy replacement: Focus on 1) new specifications for portshore power metering equipment and systems: it is necessary to regulate relevant technical standards for related measurement content changed in electrical energy substitution, that promoted complete equipment engineering application of integrated, modular, miniaturized power system in the future with the development of power electronics technology. 2)the standards for energy alternative energy efficiency assessment and testing. 3)The corresponding standards should be formulated for smart devices of electric energy replacement used in terms of safety and energy conservation with the development of smart power technology.

(13) Mobile internet device: It is necessary to revise and improve the specifications including functions interfaces and detection technology of the mobile internet device that has more functions due to the diverse ways of interacting of widespread power internet of things interactions in the future.

3.3.2. Acquisition equipment layer
(1) Formulate technical standards of energy management terminal and communication converter module for collection and copy of public utilities energy.

(2) Formulate relevant technical standards of energy efficiency monitoring and analysis terminals: including the functional requirements and detection methods of intelligent energy interactive monitoring terminal, system design, and operation and maintenance standards. It is necessary to standardize the functional requirements, technical requirements, safety protection requirements and inspection requirements of building intelligent interactive terminals and industrial user intelligent interactive terminals.

(3) Formulate standards for functions, interfaces of intelligent interactive terminal: It is urgent to establish functional and technical standards of demand response terminal for energy-using equipment of air conditioners and water heaters.

(4) Edge physical association agent equipment: Edge computing provides near-edge edge intelligence computing services, the way computing and analyzing on the device helps to reduce the latency of critical applications, edge computing is the core of the development of the internet of things
[10]. Unify standard, normalize function positioning, aiming at the new business multi-modality related edge material link agent device, that improves the level of edge intelligence and develops edge data value.

3.3.3. System platform layer

(1) Standardization study on integrated collection technology of energy (water, electricity, gas and heat) for public utilities: Certificate various types of saving electricity and electricity and formulate energy management system standards.

(2) Revise the standards of intelligent electricity service system and interactive service platform: It is necessary to formulate standards for intelligent electricity interactive service platform, which includes functional specifications, interface specifications, design specifications, safety protection specifications, communication control specifications, inspection and testing specifications and operation management specifications, etc.

(3) Integrated interface standard of intelligent electricity system: it is necessary to formulate the interface standard of intelligent interactive terminal, the integration standards of intelligent power service platform and intelligent interactive terminal, the user's in-house communication protocol and public information interaction model, etc.

(4) Interactive platform between electric vehicle, charging and replacing facilities and smart grid: In order to effectively reduce the impact of large-scale electric vehicle charging on power grid, it is necessary to formulate standards for bidirectional interaction between electric vehicles, charging and discharging facilities and smart grid.

(5) New energy system: establish standards for energy efficiency management and evaluation, monitoring and analyzing the operation of energy-using system and energy consumption of the whole life cycle by means of information technology are the future direction of technology development.

(6) Requirement response system standards: It is urgent to formulate technical standards for power demand response system that includes system function class, system technology class, system construction and operation class, system inspection class standard, etc. 1) Demand response interface standards: it includes demand side resource interface standard, other business system interface standard and information model and interoperability standard. 2) Test and evaluation criteria for demand response system: It includes demand response potential assessment, power saving measurement and verification, benefit assessment, multi-temporal demand response capability prediction and virtual reality simulation related standards.

(7) Power system cryptography application and information security related technical standards.

(8) Mass measurement data management system standards: it is necessary to formulate system functional class, system performance class, interoperability class, system testing class standards and system interoperability and testing technical standards. The key technologies of big data and cloud computing involve standards: data algorithm analysis, data storage, cloud computing network standards, cloud computing service standards, cloud computing business application standards, cloud security standards, analysis platform and tools standards.

(9) Formulate the standard of virtual reality simulation application: Virtual simulation technology is becoming more and more popular based on the characteristics of high complexity, high investment and high technology-intensive in the field of electric power. Relevant specifications need to be formulated for virtual simulation technology and application which effectively assists power field operation, training, accident simulation and on-line monitoring, etc.

(10) Mobile interconnection application software and security protection: 1) Mobile application development and evaluation technology standards. 2) Interactive standard of third party services. 3) Mobile application safety protection standards. 4) New instant communication technology, augmented reality and three-dimensional human-computer interaction system standards.

(11) Standard for integrated energy management system of domain energy internet: Formulate the technical standards of new intelligent body equipment based on the grid information physical system that supports the technical standards of multi-energy fusion, active control and protection. Formulate
standards for local energy internet energy management systems that support flexible network architectures and support for accurate computing.

3.3.4. Communication layer
(1) IoT Low Power Wide Area Network (LPWAN) Technology Application Standard.
(2) 5G: Electric power application standard of the fifth generation mobile communication system.
(3) RFID: Application standard of RFID in intelligent metering equipment.

3.3.5. Interoperability Layer
(1) Technical standards for supporting multi-Meter integrative reading communication protocol of public utilities energy (water, electricity, gas and heat).
(2) Advanced information interaction standards: it is mainly for internet of things IPv6 protocol application.
(3) Plug and play protocol: formulate the technical standards of the unified channel, data model, access mode and access protocol for accessing system of power terminal equipment to realize plug and play of all kinds of terminal equipment.
(4) Information interaction and security standards for distributed power access: research and formulate relevant norms to guarantee no large-scale offline because of network information security when a large number of distributed generators are connected to the grid.
(5) Third-party service interaction standards for mobile interconnection applications: standardize the access, interactive process, design requirements, design requirements for safety protection of of third party services and payment platform In mobile interconnection applications.
(6) Standards for interconnection and interoperability of microgrid: The technology of power flow control and interconnection among multi-microgrids will also become the direction of technology development and the field of standard formulation.
(7) Information interaction standards for local energy internet: Formulate the standards for architecture and information exchange bus of intelligent control information interaction system of local energy internet, establish a unified standards for multi-energy terminal information integration and interoperability, interface specifications, communication services and consistency testing and evaluation.

3.3.6. Safety protective layer
(1) Safety certification standards for information interaction of multi-energy (water, electricity, gas and heat) in public utilities.
(2) Security certification standards for multi-energy information interaction.
(3) Data center security: formulate data security protection technology specifications to adapt to large energy data centers, including data classification authorization, data leak prevention, application audit, security interaction and other security specifications.
(4) Physical information protection: it is necessary to revise the standards of physical information protection of chips and equipment, electricity theft prevention, water and dust prevention, data security storage, data backup trustworthiness and so on.
(5) Security defense: formulate technical specifications for improving intelligent defense and recovery capabilities of power network security based on analysis and prediction technology of artificial intelligence and security situational awareness.

4. Summary
The paper has analyzed new demand and development direction of metrology technology around the new business of the tasks of energy interconnection construction including public utilities energy services, distributed energy services, intelligent energy services, vehicle networking services, electricity substitution (energy conservation and emission reduction), etc. The paper has studied and designed a measurement standard architecture which can support the demand of energy internet based
on the existing measurement architecture. The contents of relevant standards that need to be revised or added in each layer of the system (device layer, communication layer, interoperability layer, security layer, system layer) are specifically studied, which provides guidance for the promotion and revision work of relevant standards, promotes industrial technological innovation, and supports industrial optimization and upgrading.

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