NQI Status and Demand Analysis of Intelligent Electric Energy Meter Industry

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Abstract. Taking the opportunity of undertaking the project of "NQI Typical Demonstration Application" of the key research and development projects of the state, and taking the intelligent electric energy meter as the breakthrough point, the production and use process of intelligent electric energy meter in the whole life cycle is summarized as eight links: research and development design, material purchasing, production and manufacturing, factory supply, acceptance and inspection, storage and distribution, installation and operation, dismantling of scrap and so on, and the status of National Quality Infrastructure (NQI) in intelligent electric energy meter industry is carded out. At the same time, the paper summarizes the development needs of intelligent electric energy meter industry in measurement, standards, inspection, certification and accreditation, which provides guidance and basis for the construction of NQI in smart grid measurement field.

1. Introduction

In 2016, the Ministry of Science and Technology has launched the national key research and development plan project “National Quality Infrastructure Foundation Mechanism and Evaluation Technology Research”. The project is led by the China Institute of Metrology and jointly undertaken by more than 20 units in China, including the China Institute of Standardization, the Development Research Center of the State Council and the China Academy of Electricity[1]. The National Network Metrology Center of the Chinese Academy of Electrical Sciences participated in the key project of NQI's sub-topic "NQI Typical Demonstration Application". Developing the typical demonstration application of NQI in the field of intelligent measurement can summarize the practical experience of NQI, form a replicable and popularizable application mode of NQI, comprehensively improve the development and application level of NQI in the field of intelligent measurement, promote industrial technological innovation, and support industrial optimization and upgrading[2].

Smart energy meter is the metering instrument of power trade settlement, is an important way of connection between smart grid and the vast number of power customers, is the key to ensure fair, just and accurate measurement, is the landing point of the NQI construction, has significant characteristics
to protect people's livelihood, the quality of smart energy meter is directly related to the vital interests of ordinary people[3].

Taking smart watt-hour meter as the breakthrough point, this paper analyses and summarizes the current situation and demand of NQI in smart watt-hour meter industry from the aspects of measurement, standards, inspection, certification and Accreditation of four elements of NQI, which is of great significance for improving the quality of products, making NQI scientifically guide the upgrading of enterprises' capabilities and supporting the transformation and upgrading of industries.

2. The Specific Meaning of NQI

2.1 Introduction to NQI

In 2005, the United Nations Trade and Development Organization (UNCTAD) and the World Trade Organization (WTO) jointly issued the "Export Strategic Innovation" report for the first time put forward the concept of National Quality Infrastructure[4]. In 2006, the United Nations Industrial Development Organization (UNIDO) and the International Organization for Standardization (ISO), on the basis of more than 100 years of practical experience in the field of quality, issued a study entitled "The Three Pillars of Sustainable Development - Measurement, Standards and Conformity Assessment", which formally introduced measurement, standards, conformity assessment (including inspection and testing, Certification and accreditation) together constitute the national quality infrastructure, pointing out that measurement, standards, conformity assessment has become the future world economic sustainable development of the three pillars, government and enterprises to increase productivity, maintain life and health, protect consumer rights, protect the environment, maintain safety and improve quality of important technical means[5]. In 2013, the World Bank released Response to the Global Quality Challenge - National Quality Foundation. The national quality infrastructure has formed a consensus and has attracted the attention of major developed countries such as the United States, Britain and Germany. The US "Innovation Strategy", Germany "Industry 4.0", and the EU "Horizon 2020 Plan" all regard the improvement of national quality infrastructure as a core task[6].

The national quality infrastructure supports and serves all fields of the national economy. It has the characteristics of public products, with distinctive technical, professional, systematic and international characteristics. It is not only recognized by internationally as the cornerstone for improving the quality competitiveness, but also guarantees the national economy. Technical rules for order operation, important technology platforms for promoting scientific and technological innovation, and important technical means for enhancing international competitiveness[7]. Strengthening the research and application of national quality infrastructure has important practical significance for promoting China's economic development to maintain medium and high-speed growth and to reach the middle and high-end level[8].

2.2 The Four Elements Relation of NQI

The four elements of NQI interact with each other and promote each other. Measurement is the basis of quality control. Standards lead to quality improvement. Qualification assessment (inspection, testing and certification) controls quality and establishes quality trust. The three elements form a complete technological chain, complement each other, and support the development of quality together. The relationship is shown in Figure 1. Measurement is the basis of standards and conformity assessment; standards are the basis of conformity assessment and the important value of measurement; conformity assessment is an important means to promote the level of traceability of measurement and the implementation of standards [9].
3. **Eight Links in the Life Cycle of Intelligent Electric Energy Meter**

To implement the life cycle management of smart energy meters, it is necessary to consider the whole process of planning, design, procurement, construction, operation, maintenance and scrapping of energy meters, and optimize the overall situation[10-11].

On the side of the production enterprise, the quality control of the energy meter in the procurement, research and development, production and supply process is realized through the verification of the factory qualification rate and the pre-installation qualification rate of the smart energy meter.

In the process of material procurement, we pay attention to the quality of control components, and pay attention to improving the quality of finished products in the process of R&D design and manufacturing.

On the power company side, the quality control of smart energy meters is currently divided into eight parts: procurement arrival, equipment acceptance, verification inspection, warehousing and distribution, equipment installation, equipment operation, equipment demolition, asset retirement, etc. Realize the unification and standardization of data flow, business flow and information flow in each link, and effectively control the quality of electric energy meter.

Considering the quality control process of the smart energy meter of the production enterprise and the power company, it can be divided into eight parts: R&D design, material procurement, manufacturing, factory supply, acceptance inspection, warehousing and distribution, installation and operation, and demolition and scrapping. As shown in Figure 2, these eight links contain several sub-links, which are a high-level summary of the key steps in the life cycle management of smart energy meters.

![Fig.1 NQI four factor relation diagram](image-url)
4. Current Situation and Demand of NQI in Intelligent Electric Energy Meter Industry

Based on measurement, standardization as the core, inspection and certification, and certification as a means to deeply analyze the NQI status and needs of the eight phases of the smart energy meter life cycle, which can realize the development of NQI in the smart energy meter industry and the industrial transformation and upgrading. Summary and refinement of potential demand and endogenous power. The following analysis is carried out from the perspective of the first four links (the production company side) and the last four links (the power company side).

4.1 Production Enterprise Side

4.1.1 NQI status quo

(1) Measurement

When collecting R&D needs and formulating technical plans, the main parameters such as electrical parameters, environmental parameters, functional parameters and structure should be clearly defined. In product development, traceability should be made to the equipment, environment and measuring instruments used in research and development.

The measurement management level of domestic device manufacturers is uneven, which results in a certain gap between the quality stability and consistency of domestic devices and foreign brand devices.

Electric energy meter production equipment and testing equipment (instruments, measuring instruments) are periodically checked and daily checked to ensure the normal operation of equipment and instruments.

It is required that the highest-grade standard device should have valid certificate issued by the Institute of Metrology Research. Other verification equipment and appliances should be valid within the validity period and can be traced back to the highest-grade standard device.

(2) Standard

In product development, reliability models, reliability allocation, reliability prediction, failure modes, impact and hazard analysis, circuit tolerance analysis and reliability design criteria can be established.

In the part of requirement analysis and sample confirmation, there are many standards and standards, such as customer technical standards, component national standards, component industry standards, and so on. In the part of supplier management, there are some differences in the content and standard of supplier evaluation among manufacturers.
Introduce international advanced standards and domestic related standards, formulate enterprise implementation standards, and formulate process documents and inspection specifications according to standards, so that production and manufacturing can be based on evidence.

According to GB/T 17215 series, IEC 62052 series, JGG596-2012, Q/GDW national network series, Q/CSG Southern Network series, factory inspection and internal back-off table management are carried out.

(3) Inspection and Testing

When collecting R&D needs and formulating technical plans, formulate product standard strategies, formulate product concepts and technical plans, formulate product quality and cost objectives, and confirm product manufacturability requirements.

In the part of requirement analysis and sample confirmation, we have set up an internal testing and Analysis Laboratory for components and materials, which has the ability of material detection and failure analysis. In the supplier management section, periodic sampling reliability test is carried out for the normally used device materials.

First inspection, spot inspection and patrol inspection are carried out according to standards and specifications for each production quality control point. Visual inspection (appearance) and equipment inspection (performance) are used for inspection, and corresponding inspection records are made.

Out-of-factory supply has realized automation, informatization of inspection items, automatic upload of inspection results to FIS system, automatic system judgment, quality appraisal, and complete elimination of manual missed detection.

(4) Certification and Accreditation

Domestic certification and accreditation institutions: Zhejiang Academy of Metrology, China Academy of Electric Power Sciences, South China Grid Research Institute, China Electrical Instruments Quality Supervision and Inspection Center and provincial relevant power agencies, CNAS laboratory accreditation. International certification includes STS certification, MET certification, KEMA certification, MID certification, FCC certification, etc.

At present, suppliers can be required to issue third-party laboratory reports such as the National Network Metrology Center test report, Saibao and some authoritative certification as required.

Enterprises have obtained ISO 9001 Quality System Certificate, ISO 14000 Environmental System Certificate, ISO 18000 Safe Occupational Health System Certificate and Measurement Management System Certificate.

The existing quality system and products need to be certified by the state authority, such as ISO9000, ISO14000, ISO28000, ISO10012, or MID, SGS, CE, KEMA and other products.

4.1.2 NQI Demand

(1) Measurement

In order to improve the measurement accuracy and reliability of electric energy meter, in the research and design of intelligent electric energy meter, in the process of product demand formulation, the measurement grade can be reduced and tightened, and the product grade can be revised.

At present, many meters manufacturing enterprises have established laboratories, so it is necessary to continue to improve the detection ability of enterprises'internal laboratories, continue to promote the research on the uncertainty of measurement results in meters manufacturing enterprises, and form a perfect measurement and testing system.

We will expand R&D and production of high-precision and high-performance meters, upgrade the quality level and international competitiveness of domestic meter manufacturing, and actively participate in the competition in the international high-end market.

State Grid Corporation needs to issue standards for test benches and automatic lines, and unify the types of test benches and accuracy requirements of each power supply bureau.

(2) Standard

In product R&D demand collection and program formulation, promote the development of national grid standards to alliance standards, establish product quality and grade evaluation standards, and
promote enterprise product quality improvement and supplier evaluation rules optimization. In the stage of product development, the standard deviation of reliability series related to product operation quality is large, and the industry failure data need to be revised. In R&D verification, the processing standards after product sorting should be formulated.

According to the characteristics of all kinds of electronic components, the normal allowable failure rate should be set in the lifetime of the national network, which can guide domestic manufacturers to do a good job in the analysis and calculation of the basic failure rate of the devices, improve the reliability testing level and enhance the failure analysis ability of the devices.

The State Grid Corporation unifies the inspection and testing standards of provincial bureaus, especially the testing software testing and judging standards of automatic detection lines. Through the unification of inspection and testing standards, the work efficiency of inspection and testing of provincial bureaus is improved.

Comprehensively check the international standards, understand the reasons for the differences between standards, and clarify the different market inspection standards and judgment criteria.

(3) Inspection and Testing

In product R&D demand collection and program formulation, information systems and ways are needed to form a sharing and closed-loop mechanism. In product development, software reliability needs to be tested by MCU core board promoted by Academy of Sciences. In product R&D certification, it is necessary to achieve the consistency of testing methods and criteria between enterprises and power customers.

In the process of material purchasing, efforts should be made to improve reliability testing level and device failure analysis capability, and the research results of related methods of material inspection can be shared among manufacturers.

It is necessary to continuously introduce advanced production equipment (such as high-precision calibration table) and detection equipment (such as high-resolution AOI machine) to improve the inspection and detection capability of the watt-hour meter manufacturing process.

For the sharing of external testing schemes and testing information, special markets and special projects need to be clearly defined and uniformly released.

(4) Certification and Accreditation

It is hoped that all authoritative laboratories and institutions at home and abroad will promote mutual recognition mechanism, reduce the cost of certification and the time of certification, and improve efficiency.

While guaranteeing the fairness of accreditation, we should unify the standards of accreditation, improve the validity of accreditation, integrate the resources of accreditation, and establish a unified system of accreditation.

Establishing the evaluation and certification system of watt-hour meter and realizing mutual recognition with the international authoritative inspection organizations, it is urgent to establish the evaluation and evaluation system of production and manufacturing, so as to promote the watt-hour meter production enterprises to continuously improve their production and manufacturing level.

It is hoped that CNC will comprehensively check the international standards, understand the reasons for the differences between standards, and ultimately output decision-making opinions and reasons, gradually achieving mutual recognition of national and national as well as internal testing of institutions and enterprises.

4.2 Power Company Side

4.2.1 NQI status quo

(1) Measurement

For traditional watt-hour meters, all levels of metering centers and metering verification agencies have built various levels of electric energy verification devices, according to the corresponding verification rules, to verify the disassembled watt-hour meters.
At present, the full-performance test series devices can analyze the reasons for the faulty watt-hour meter, but they lack the traceability of measurement accuracy under the dynamic signal (fractional harmonics), the reliability test and evaluation system of watt-hour meter software, etc.

China Academy of Electrical Sciences, Chongqing Academy of Electrical Sciences and other units have established a platform for analyzing the operation status of electric energy metering devices, and established an expert scoring model for the operation status of electric energy meters from the management point of view, so as to achieve the purpose of state assessment.

At present, provincial centers and prefectural and municipal companies have manual verification devices for watt-hour meters, automatic verification systems for watt-hour meters and other verification equipment, and the measurement standards are traceable. Through the close combination of MDS system and SG186 system of power supply company, the measurement center of national power network obtains the information of user's electricity consumption, the scrap rate of statistical tables and the operation status of meters.

(2) Standard

For traditional watt-hour meters, the national standards mainly include JB/T 50070-2002 "Reliability Requirements and Assessment Methods of Watt-hour Meters", Q/GDW 11116-2013 "Technical Specification for Software Design of Intelligent Watt-hour Meter Detection Devices", and the national grid enterprise standard "Technical Specification for Software Reliability Testing of Intelligent Watt-hour Meters".

At present, the sorting and disposal link refers to the Guiding Opinions of State Grid Corporation on the sorting and disposal management of smart watt-hour meters. Asset scrapping link is based on the "State Grid Corporation Measuring Assets Life Cycle Management Measures", and the result of scrapping is issued by the prefectural and municipal companies. The management method for sorting and diagnosing smart watt-hour meters in the State Grid company, which is still under development, puts forward that fault diagnosis information, analysis report and spot check certificate of smart watt-hour meters should be included in the fault database of smart watt-hour meters.

(3) Inspection and Testing

The provincial Metrology Center compares the samples and software according to the pre-arrival inspection samples and software records, carries out the sampling inspection after arrival and the After-arrival inspection and receipt test according to the national verification regulations and relevant standards.

Intelligent performance field testing equipment, methods and processes need to be improved. Intelligent performance field installation and debugging points are wide, lack of process control, installation process can not be guaranteed.

If customers apply for calibration, the calibration standard can refer to the verification rules in the process of sample inspection of electric energy meters, but according to the actual situation, it can also simulate the on-site operation, such as the magnitude of load current, load type, etc.

The provincial central re-inspection link adopts relevant verification rules and technical specifications to conduct a full inspection of the watt-hour meter, which is a statutory metrology authorization body and provides verification results in accordance with the law. However, there is no corresponding standard to regulate the sorting inspection and testing of city (county) companies.

(4) Certification and Accreditation

From the point of view of national network management, the national network Metrology Center carries out full performance testing in accordance with the national verification regulations and relevant standards. The Provincial Center is a statutory metrology authorization agency, which issues the verification results according to law and enters the qualified testing into the MDS system. Provincial Metrology Center issued a notice of eligibility for adaptability inspection, and signed a supply contract and a supply notice with qualified suppliers.

Laboratory failure testing is authorized by CNAS. The verification of traditional watt-hour meters and traditional gateway watt-hour meters is carried out according to the regulations and authorized by the government. There is no authentication method for digital watt-hour meter.
The provincial Metrology Center and the national network Metrology Center all have the certification of relevant inspection and testing, and can carry out intelligent meter fault diagnosis. There is no accreditation and certification required for metrological verification in all municipalities and power supply stations.

4.2.2 NQI Demand

(1) Measurement

It is suggested that the test results of the watt-hour meter components in the national network metering center should be shared with the supplier's test data, and the preliminary judgment of the quality stability and consistency of the components should be made through the large data, so as to provide data support for the selection of the components.

It is necessary to study the operating state parameters of electric energy metering devices to achieve accurate state evaluation. The traceability of measurement accuracy under dynamic signals, the software reliability test and evaluation system of watt-hour meter are studied, and the fault analysis method and detection device of digital watt-hour meter are studied.

The sorting device for disassembling electric energy meter is developed, and the source of sorting device is traced in the follow-up. Centralized detection, classification, reduce detection costs, maximize the reuse value of energy measurement assets. Complete the design of disassembly and storage, equipment sorting and classification disposal in the marketing system.

(2) Standard

At present, there is still a lack of unified standards for the automatic line process of watt-hour meters, and there is a lack of unified regulations in the automatic line process detection. At the same time, there is a lack of related technical standards for software reliability and watt-hour meter life detection to standardize software reliability detection and watt-hour meter life detection. As well as the lack of unified pre-production adaptability testing methods, it is necessary to unify the pre-production adaptability testing methods.

Establish and improve the "Intelligent Watt-hour Meter Distribution (Repository) Quality Work Assessment Management Measures", according to the requirements of the quality control point, in the management methods, clear inspection and testing work content, workflow, the use of tools and other content.

To formulate relevant standards for the disassembly and retention of watt-hour meters, sorting and classification of watt-hour meters, and to continue to improve the verification rules and technical specifications for verification and detection. Complete the "State Grid Corporation Removal of Intelligent Watt-hour Meter Sorting and Diagnosis Management Method" formulation, and the management method is applied to the corresponding business processes.

(3) Inspection and Testing

In the process of acceptance and testing, there is a lack of software reliability, related technical standards for watt-hour meter life detection and laboratory certification standards for watt-hour meter testing.

Research on digital watt-hour meter metering verification device and verification rules, and bring digital watt-hour meter into periodic verification management rules. Develop on-line measurement and verification methods, and study and determine the sampling inspection items of digital watt-hour meters. It is suggested to use the on-site construction recorder as a means and evidence for quality control of installation. Perfect the simulation repetition test method of complex working conditions in the field, and study the fault analysis method of digital watt-hour meter which can simulate complex environment in the field.

Improve the fault library of intelligent watt-hour meter. It is necessary to improve the function of provincial central review link of MDS system.

(4) Certification and Accreditation

Based on standards and technical specifications, advanced management means such as system management, process control and excellent performance are used to play a fundamental role in
improving quality management. Authoritative certification mechanism for suppliers of watt-hour meters and certification of watt-hour meter testing laboratories in the alliance are established to meet the needs of watt-hour meter manufacturers for supply. The certification of commercial qualification and capability level and the requirement of quality certification in the process of acceptance and inspection of watt-hour meters.

Further formulate and improve the certification and accreditation system such as "Measures for Accreditation and Accreditation of Intelligent Storage System for Measurement", and sort out the contents, relevant methods and processes of certification and accreditation, and the certification agencies involved.

Based on the operation status information of intelligent watt-hour meter, the state analysis model and the state evaluation model authentication system are established.

5. Concluding Remarks
At present, the research of NQI is still in the stage of catching up with the advanced level of the world. In the project "Research on the Mechanism and Evaluation Technology of National Quality Foundation (NQI)", there are corresponding sub-topics to study the macro and micro mechanisms, dynamics and models of NQI, and to study the development roadmap of NQI quality foundation in key areas. Based on these studies, the sub-topic "NQI typical demonstration applications" selected representative enterprises in the fields of machinery, electronics, smart grid and other fields to carry out NQI upgrading demonstration applications, to verify how the integrity and support of NQI can be embodied and implemented in enterprises.

In the field of smart grid, as a high-tech enterprise, China Academy of Electrical Sciences has achieved initial results in NQI construction. In the field of smart grid measurement, smart watt-hour meter as an example, with the improvement of national grid technical standards, verification and detection methods, and the continuous improvement of domestic meter manufacturers' R&D and manufacturing level, the quality of domestic meter has made a qualitative leap. In the international middle and low-end markets (such as the African market and the Southeast Asian market), Chinese meter enterprises account for a considerable proportion and have established a good reputation. However, China's smart meter enterprises have a very low share in the high-end market (such as the European Union, North America and other countries), and their quality and brand image are poor. Establishing and improving NQI system based on the whole life cycle of watt-hour meter will help us to further improve the overall quality of domestic meters, accelerate the development and production of high-end products, open up the international high-end market, and make the technology and quality of domestic watt-hour meter products stand in the forefront of the international watt-hour meter industry.

This paper summarizes and refines the eight links of the whole life cycle of smart watt-hour meter, and combines the eight links to analyze the current situation and demand of NQI in smart watt-hour meter industry, which provides the basis and guidance for formulating the top-level design and construction of NQI in the field of smart measurement. It helps to improve product life, reduce product failure rate and reduce equipment operation and maintenance costs; helps to form a one-stop service system of the whole industry chain based on NQI, to promote industrial innovation and development, transformation and upgrading; helps to build a quality evaluation system of four elements of NQI coordinated development, to lead high-end intelligent manufacturing, and to support national quality. The strategy of developing a powerful country will help push the high-quality products to the international high-end level, realize international mutual recognition, enhance the international competitiveness of China's manufacturing, serve the "one belt and one road" and build a modern socialist country.
Acknowledgments
This work is supported by Science and Technology Project of SGCC. (Research and Demonstration Application of NQI Key Technologies Supporting Intelligent Electric Energy Meter Quality Improvement, No. SGHADK00JLJS1900063).

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