Domestic Smart Meter Demand Assessment

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Abstract

During the "13th Five-Year Plan" period, the State Grid smart meter market will undergo significant transformation, wherein demand for smart meters will decline substantially while demand for supporting equipment such as pluggable meter boxes will increase. Confronted with this market shift, traditional meter enterprises must accelerate diversification development of meter products to adapt to emerging market demands. On one hand, beyond traditional markets for meters, terminals, and pluggable meter boxes, attention must also be directed toward promising meter market segments, including statistical meters integrated with electricity consumption monitoring and low-voltage grid maximum load measurement and control systems, four-meter integration acquisition, low-voltage metering boxes, and low-voltage cabinet series products. These markets will furnish new growth points for meter enterprises. On the other hand, demand for mainstream products in the non-centralized procurement market warrants significant attention. This market's requirements encompass statistical meters, all-in-one card detection sockets, industrial input/output (I/O) modules and various monitoring systems, and integrated energy consumption data management systems for electricity, water, gas, heat, and cooling meters. These products will contribute to enhancing the intelligence level of meters and satisfying diverse user requirements. Moreover, development of innovative smart meter products constitutes a crucial future direction. These innovative products will facilitate improvements in meter accuracy, stability, and reliability, thereby elevating the intelligence level of power grids. In summary, during the "13th Five-Year Plan" period, meter enterprises must keep pace with market changes, accelerate product diversification development, and enhance product intelligence levels to accommodate new market demands. Simultaneously, both government and enterprises need to intensify support for meter technology innovation to propel technological advancement and industrial upgrading in the meter industry.

Full Text

Introduction

The year 2016 marks the beginning of China's 13th Five-Year Plan period. With the rapid advancement of "Internet Plus," urban energy internet, and smart distribution network construction, new requirements have been imposed on the modernization of grid measurement technology. In 2017, the State Grid Corporation of China (SGCC) will complete the world's largest electricity information collection system, achieving full smart meter coverage for 395 million households. Meanwhile, as the first batch of smart meters enters their rotation and replacement cycle, the 2013 edition of SGCC's smart meter series enterprise standards may be revised and updated. Consequently, the market and technology trends for domestic smart meters during the 13th Five-Year Plan period warrant timely discussion and planning.

1) Market Composition Elements for SGCC Smart Meters During the 13th Five-Year Plan

In 2016, SGCC "installed 60.58 million smart meters, achieving basic full coverage of the company's electricity information collection." Based on calculations, SGCC's collected users will reach 377.58 million, with a total collection coverage rate of 95.5% and annual new smart meter investment of 23 billion yuan.

For the remaining four years of the 13th Five-Year Plan, SGCC's smart meter market elements are as follows:

New smart meter installations: With annual new users calculated at 4% of SGCC's total users, 15.8 million smart meters will be needed annually. Over the four-year period, demand will reach 63.2 million smart meters, representing an investment of 24 billion yuan.

Smart meter promotion: Replacing conventional meters with smart meters, including achieving full coverage of electricity information collection and meters for counties under SGCC management through wholesale or trusteeship, will account for 7% of SGCC's total users annually, requiring 12.35 million new smart meters per year. Over four years, demand will reach 49.42 million smart meters, with an investment of 18.8 billion yuan.

Smart meter rotation: Starting from the first batch of smart meters deployed in 2010, meters reaching an 8-year operational cycle will require rotation and replacement. Calculated at 2% of SGCC's total users annually, 7.9 million smart meters will be needed each year, totaling 31.6 million smart meters over four years, with an investment of 5.6 billion yuan.

Combined total: During the 13th Five-Year Plan period, SGCC will require a cumulative total of 204.7 million smart meters, with an average annual demand of 40.94 million units—a 31% decrease from the average annual demand of 60

million units during the 12th Five-Year Plan. Total investment in smart meters will reach 71.4 billion yuan.

Smart meter supporting equipment: Plug-in meter boxes. Over the five-year period, SGCC's new plug-in meter boxes will account for 12% of SGCC's total users in terms of meter positions, requiring 47.4 million meter positions with a total investment of 7.1 billion yuan.

2) Accelerating Diversified Product Development to Adapt to Market Changes

Over the past seven years, traditional meter enterprises have primarily focused on the centralized bidding market for SGCC and China Southern Power Grid smart meters, concentrating on ensuring metering product quality. These enterprises have benefited from and developed within a stable market with modest demand for new products. Facing these new circumstances during the 13th Five-Year Plan, traditional meter enterprises need to consider and deploy diversified development of meter products to cultivate and expand new markets.

Based on the comprehensive application of SGCC smart meters and the progress of electricity information collection system construction entering its later stages, the authors have successively written relevant manuscripts on smart meter market outlook predictions and countermeasures since September 2015, including: "Market Prospects for Traditional Meter Enterprise Development in 2015 and Beyond" (September 2015), "Assessment of Measurement Technology Requirements in the Distribution Network Construction and Transformation Action Plan (2015-2020)" (2015), and "Preliminary Exploration of Smart Electric Energy Metering System Technology" (published by the "Grid Measurement Technology WeChat Official Account" in April 2016).

Summarizing these manuscripts and incorporating recent demand for new metering products, the authors have identified diversified development projects for meter products in the coming years.

First, beyond the three basic markets of meters, terminals, and plug-in meter boxes, what other promising and relatively large meter markets exist?

- **Statistical meters + electricity consumption monitoring + low-voltage grid maximum load measurement and control systems.** Reference product: ABB's Emax2 low-voltage circuit breaker and its low-voltage power load measurement and control system, the world's first of its kind.
- **"Four-meter integration collection"** (electricity, water, gas, and heat). It is recommended to promote grid community water supply leakage measurement management and develop intelligent water supply terminals, with intelligent gas and heat supply terminals to follow.

- **Low-voltage metering box and low-voltage cabinet series products**
- **Digital meters and metering cabinet series products**
- **Electric vehicle charging pile energy meters**
- **Photovoltaic grid-connected energy meters and online monitoring systems**
- **Rural well electricity metering and prepayment systems**
- **User harmonic energy consumption assessment testers based on the IEEE 1459-2010 standard**
- **New-type combined instrument transformers and low-loss distribution transformers**, including amorphous alloy distribution transformers, high overload capacity distribution transformers, and capacity/voltage regulating distribution transformers.

Second, mainstream product demand in the non-centralized procurement market

Self-procurement users in the non-centralized procurement market include county-level power supply enterprises not managed by SGCC or China Southern Power Grid, prefecture-level city power supply enterprises (non-centralized bidding products), oil fields, mining operations, high-voltage dedicated transformer users, low-voltage commercial and industrial users, large convention center projects, institutions of higher education, large county-level or above hospitals, and mid-to-high-end hotels.

Main metering product demands in the non-centralized procurement market include: - **Statistical meters**, including single-phase/three-phase DIN rail meters, adapter-type smart sockets, panel-mounted smart sockets, and power adapter metering strips, along with remote meter reading systems. - **All-in-one card detection sockets** with energy metering and card-based prepayment functions. - **Industrial input/output (I/O) modules and various monitoring systems**. - **Integrated energy consumption data management systems** for electricity, water, gas, heat, and cooling meters.

Third, innovative smart meter products will be discussed in detail in Section 3.

3) Expectations for Innovative Smart Meter Product Development

Summarizing application experience from the 2009 and 2013 editions of SGCC's smart meter series enterprise standards and referencing "Preliminary Exploration of Smart Electric Energy Metering System Technology," the authors propose recommendations for domestic smart meter innovative product development projects during the 13th Five-Year Plan period.

First, adopt full-power algorithm design for smart meters

Three-phase smart meter full-power design should calculate active power, reactive power, distortion power, and apparent power for non-sinusoidal waves,

primarily referencing the IEEE 1459-2010 standard. International reference product: GE's KV2C™ three-phase meter with distortion power factor metering capability.

Single-phase smart meter full-power design should calculate active power, reactive power, and apparent power for sinusoidal waves.

Why should smart meters adopt full-power design?

According to field sampling data from large users, 60% of large users have three-phase voltage harmonic content within 5% (not exceeding standards), but three-phase current harmonic content seriously exceeds standards. This means large users have significant distortion power components and low distortion power factors, with line loss components increasing due to distortion power. Existing three-phase energy meters cannot correctly reflect harmonic power, making it impossible to provide metering data for formulating harmonic power suppression electricity pricing policies.

Single-phase smart meters using full-power calculation can verify the orthogonality of active power and reactive power calculations. Existing single-phase smart meters only require active energy metering and cannot reflect reactive power distribution in residential areas or the impact of reactive power on distribution transformer area line losses.

Full-power design for smart meters can ensure metering data reliability. When certain metering data is lost due to interference, the meter can perform self-recalculation.

Second, re-enable switching power supply design in voltage circuits

The existing SGCC smart meter functional specification Q/GDW 1354-2013 standard stipulates: "Critical voltage—the minimum voltage at which the meter can start operating—is 60% of the reference voltage." Consequently, SGCC smart meter voltage circuits adopt transformer design. From years of application experience, transformer design operates stably, but the meter's low-voltage operating range is too narrow, 不适应三相四线制电路严重不对称运行的计量需求，过电压承受能力较差，整表重量太重。

Currently, most international and exported domestic meters adopt switching power supply design in voltage circuits, with operating ranges as low as 20-30% of reference voltage and much lighter overall weight. Ten years ago, domestic electronic meters once adopted switching power supplies, but the main issues were low switching power supply reliability, excessive harmonic content in voltage circuits, and relatively high prices. These problems have been basically resolved through long-term design improvements.

Third, design multiple accuracy classes for single-phase smart meters

Existing SGCC "Technical Specification for Single-Phase Smart Meters Q/GDW 1364-2013" stipulates that "the accuracy class of single-phase smart meters is Class 2 for active energy. The meter error limit is $\pm$1.0% (0.1Ib $\leq$ I $\leq$ Imax)

at power factor 1, with factory errors controlled within 60% of the error limit value."

SGCC has 359 million single-phase users. Class 2 accuracy for active energy metering only is inappropriate. Currently, the maximum monthly electricity consumption of urban residents differs from the minimum consumption of rural residents by 60-100 times. Simultaneously, anti-electricity theft requires detection starting from 1 kWh in single-phase smart meters. The authors recommend that domestic single-phase smart meters should be designed with four accuracy classes—0.2, 0.5, 1, and 2—for four categories of single-phase users: monthly consumption of 500 kWh and above, 200 kWh and above, 100 kWh and above, and below 100 kWh.

Meanwhile, Class 0.2-1 single-phase smart meters should be designed with typical daily load curve recording to assist in analyzing abnormal user electricity consumption. Single-phase smart meter error limit requirements should be consistent with the meter's accuracy class for greater rationality.

Fourth, simplify meter types and increase built-in switch capacity to 100A

According to SGCC smart meter functional and technical specifications, Class 1 and 2 smart meters have 25 meter types, with built-in switches of 5(60A)/1.5(6)A and external switches of 10(100)A.

If smart meter built-in switches are increased to 100A, the external switch category can be eliminated, reducing Class 1 and 2 smart meter types by nearly 50%, correspondingly decreasing meter inventory and simplifying smart meter installation and replacement procedures.

SGCC smart meter standards set built-in switches at 60A, which is relatively low. This likely considers two factors: high current easily burns out meters, and domestic built-in switch quality is inadequate. The authors recommend bulk import of international 120A built-in switches to 倒逼国产内置开关提升 100 安的产品质量。Regarding heating and metering faults caused by high current, the main reasons are the use of aluminum wires or poor-quality copper wires, non-circular meter wiring terminal holes, or problematic crimping structures. These issues are not difficult to resolve through careful selection of wire materials according to specifications, improvement of meter terminal block design, and strengthening of meter installation quality management.

Fifth, focus on researching how domestic smart meters can achieve high-quality design

- **Starting from the hot topic of smart meter reliability prediction technology:** In recent years, smart meter reliability prediction reports have been mandatory bidding documents in SGCC centralized procurement. Professional journals frequently publish articles on smart meter reliability prediction and verification testing.

The June 2016 technical exchange meeting for the "Research on Full Performance of Grid Gateway Metering Master Meters" project in Yinchuan pointed out that a relatively complete set of meter reliability prediction standards has been formed internationally. Verification shows that the national standard GB/T 17215.941-2012/IEC 62059-41:1996 for smart meter reliability prediction focuses on stress models—component stress models that convert failure rates under reference conditions to failure rates under operating conditions—primarily referencing IEC 61709. The main reference manuals for component failure rate data are Siemens' SN29500 component failure rate technical specification and the IEC 62380-2004 reliability data handbook.

According to manuscripts from Landis+Gyr (Zhuhai) and Hubei Electric Power Research Institute on "Electronic Energy Meter Life Estimation and Application of Long-Life Energy Meters," SN29500 is more suitable for reliability assessment of electronic products in the power, electrical, automation, and instrumentation industries. Its data confidence level has gained widespread recognition and serves as the basis for the IEC 61709 standard.

The UK Gas and Electricity Markets Authority (OFGEM) is currently the only international professional certification agency that conducts reliability assessment and testing of metering instruments such as electricity and gas meters based on the SN29500 standard. It primarily conducts fixed-time and fixed-number censoring reliability environmental simulation tests, verifying the confidence level of theoretical data on the reliability curve at test life points based on cutoff test time and cumulative failure rate. If reliability test results align with theoretical analysis, the product's life curve is considered credible.

As early as 2004, Landis+Gyr's UK subsidiary produced the 5235A type 5(100)A, Class 1 electronic meter, which received a 20-year long-life certificate from OFGEM.

Currently, domestic smart meter reliability prediction application research primarily references GB/T 17215.941-2012/IEC 62059-41:1996 and GJB/Z 299C. There remains a significant gap between this combined application level and the combined application of IEC 61709 and SN29500 standards, basically catering to the requirements of low-priced domestic smart meters with preferred ordinary electronic components and medium-grade quality. Regarding research on smart meter effective life assessment technology, no relevant reports have been seen.

- **Common industry responsibility:** Since 2005, domestic electronic meters have dominated the domestic meter market. It is estimated that approximately 90 million smart meters will be sold domestically in 2016, with 47 million meters exported. However, due to the low international certification requirements for domestic meters' metering performance, especially quality factors, domestic high-end meters have difficulty entering the international high-end market. Consequently, how domestic smart meters can be designed and sold according to high-quality standards is a key task for innovative development in the meter industry and a common in-

dustry responsibility for meter enterprises and grid metering departments.

During the 13th Five-Year Plan period, the focus of domestic smart meter reliability research should shift from reliability prediction to reliability technology management system research, particularly focusing on research and construction of Chinese meter enterprises' energy meter reliability technology systems.

Smart meter reliability technology management has extensive and in-depth research content, mainly including smart meter field data, early failure, product reliability design, product reliability prediction, meter reliability assessment, and metering characteristic stability testing.

The June 2016 technical exchange meeting for the "Research on Full Performance of Grid Gateway Metering Master Meters" project proposed that current smart meter reliability research should focus on:

- Collecting and translating 12 relevant international standards referenced by the IEC 62059 series standards in the field of electronic equipment reliability, particularly IEC 61709 and SN29500 standards.
- Accelerating the construction of a component failure rate database for domestic smart meters and terminals, using SN29500 as the baseline to establish a graded database for domestic/imported component failure rates.
- Conducting comparative or complementary research on two types (international and domestic) of smart meter reliability prediction and verification testing methods based on practical, credible principles that promote meter quality upgrading, to select optimized typical smart meter prediction schemes.
- Conducting research on smart meter effective life assessment methods and verification testing technology to establish authoritative smart meter reliability testing.
- Conducting research on smart meter metering characteristic stability testing.
- Researching and implementing the construction of Chinese meter enterprises' energy meter reliability technology systems, currently including: smart meter field operation data collection, early failure prevention measures, product reliability design (especially derating design, thermal design, and capacity design), quality control measures in production processes, testing, packaging, transportation, and installation, meter reliability accelerated testing, meter effective life assessment and verification testing, meter metering characteristic stability testing, and meter reliability standard series, reliability information networks, and intelligent decision-making systems for the entire manufacturing process reliability.

Sixth, continue cooperative research on new domestic high-end meters with international high-end meter quality standards

- Recently, *Electrical Measurement & Instrumentation* published an article on the 0.05 Class mounted standard meter launched by Beijing/Luoyang Srier Company, which adopts ultra-high-precision full-hardware vector

TDM multipliers and built-in two error calculators with accuracy better than 0.0001%. One application is for grid gateway meter remote verification systems, replacing grid gateway auxiliary meters to conduct online real-time monitoring of three-phase gateway master meters and large user meters.

The authors recommend installing 0.05 Class mounted standard meters in parallel operation with grid gateway master and auxiliary meters to assess the variation of existing grid gateway master meters (imported) and auxiliary meters (domestic), providing 24-hour metering variation data for domestic high-end meter design improvement.

- In May 2016, the authors' manuscript "Why Hasn't Domestic High-End Meters Entered the Grid Gateway Metering Master Meter Position for a Long Time?" proposed specific approaches for continuing cooperative research on how domestic high-end meters can enter the grid gateway metering master meter position:

Further research on existing grid gateway metering master meter full performance testing technology: - **Metering performance testing technology**, focusing on metering stability assessment methods, conducting extremely low-load metering error quantitative testing and meter combined maximum error calculation according to IR46 requirements. - **Meter reliability technology**, adopting IEC 61709 and SN29500 standards for meter reliability prediction research and application. - **Research on imported high-end meter design characteristics**, with provincial grid electric power research institutes, large meter enterprises, and the authors cooperating to develop grid gateway metering master meter technical requirements referencing imported high-end meter quality standards. - **Advocating the meter industry to develop toward high-end metering**, with large meter enterprises and grid metering departments sharing industry responsibility. Large meter enterprises should increase talent and capital investment in new domestic high-end meter development, researching and developing new domestic high-end meters with international high-end meter quality standards. Grid metering departments should arrange parallel operation of new domestic high-end meters with imported high-end meters for meter comparison testing, assessment, and design improvement. It is hoped that new domestic high-end meters will enter the grid gateway metering master meter position at an early date.

Reference: [1] Zhang Chunhui, Zhang Zhen. Assessment of the demand for smart meters in China.

Note: Figure translations are in progress. See original paper for figures.