Research on Performance Differences Between Domestic and Imported High-end Energy Meters and Their Testing Technologies

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Abstract

Grid gateway metering represents the most critical metering points in the power grid, necessitating the selection of high-end electricity meters as primary meters for grid gateway metering. For an extended period, despite imported high-end meters being priced 8-10 times higher than comparable domestic counterparts, grid authorities have consistently selected imported high-end electricity meters as the primary meters for grid gateway metering. Extensive laboratory and on-site load-based metrological assessments over many years have demonstrated that imported high-end meters maintain stringent control over metering errors and exhibit stable performance, thereby earning an excellent reputation and credibility. Domestic high-end electricity meters, following more than two decades of development, have achieved dominance in the domestic electricity meter market; however, they have yet to attain primary meter status for grid gateway metering, representing a developmental shortcoming within the electricity meter industry. Promoting domestic high-end electricity meters into the primary meter position for grid gateway metering constitutes a long-term strategic issue for the planning and design of the electricity meter industry.

Full Text

Performance Differences Between Domestic and Imported High-End Electricity Meters and Their Testing Technologies

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Abstract: Grid gateway metering represents the most critical measurement point in power networks, requiring the selection of high-end electricity meters

as the primary metering devices. For a long time, despite imported high-end meters costing 8-10 times more than their domestic counterparts, grid authorities have consistently chosen imported meters as the master meters for grid gateway metering. Years of laboratory and field load testing have demonstrated that imported high-end meters maintain strict control over metering errors and exhibit stable performance, earning them an excellent reputation and credibility.

Correspondingly, domestic high-end meters have dominated the domestic market after more than 20 years of development, yet they have failed to achieve the status of master meters for grid gateway metering, representing a developmental shortcoming for the industry. How to promote domestic high-end meters into this position is a long-term strategic issue for industry planning and design.

To address this, during 2006-2007, Wasion Group, Zhengzhou Wante Company, Chongqing Electric Power Research Institute, and the authors collaborated on research into quality testing technologies for domestic versus imported high-end meters. In 2008, Zhengzhou Wante Company first launched a three-phase multifunction meter quality testing device in China. During 2009-2010, Chongqing Electric Power Research Institute submitted its first "Grid Gateway Meter Performance Test Report" to the State Grid Corporation and published the paper "Preliminary Exploration of Grid Gateway Meter Performance Testing Technology." Simultaneously, Wasion Group developed a Class 0.1S three-phase multifunction meter and implemented batch applications in power grids.

Given the need for domestic high-end meter quality technology to reach international standards, the "Modern Grid Measurement Technology Collaborative Research Platform" convened two technical exchange meetings on the "Full Performance Research on Grid Gateway Metering Master Meters" in 2014 (Changsha) and 2015 (Yinchuan). As a first step, these meetings discussed preliminary research results on performance differences and testing technologies between domestic and imported high-end meters.

I. Performance Testing and Analysis of Grid Gateway Metering Master Meters

1. Chongqing Electric Power Research Institute: "Grid Gateway Meter Performance Test Report" Through performance testing and comparison of multiple gateway meters, a particular model demonstrated several key metering characteristics:

1) From 0.05%In to full scale, the basic error curve remained flat with measurement errors <0.05%. Across various power factors, measurement errors were <0.08%.
2) High-precision reactive power measurement met Class 0.5 requirements, exceeding current IEC reactive meter standards.

3) At extremely low power factors—for example, when phase angle was 90°$±$0.5°—measurement errors remained <1%, indicating error adjustment and control for power factors <0.25.
4) Bidirectional metering accuracy from 0.05%In to full scale.
5) However, the overload and high-voltage characteristics of this gateway meter model were slightly inferior.

2. Wasion Group: "Analysis of a Grid Gateway Meter Model" Design features of this gateway meter model:

1) **Metering scheme:** Controls linearity of high-precision measurement during power load and phase changes.
2) **Power supply scheme:** Uses three-phase PT and auxiliary power supply simultaneously; the meter operates normally as long as one-phase PT or auxiliary power supply is functioning.
3) **Power outage state:** Built-in supercapacitor supports clock operation and outage data reading for 30 days; optional lithium battery can support 10 years.
4) **Management scheme:** Implements advanced multifunction capabilities; measurement system and communication system are completely independent.
5) **LCD and keypad:** (Details omitted)
6) **Components:** Uses long-life, high-stability branded components.
7) **Structural design:**
    - Multiple circuit boards facilitate product series development
    - Circuit boards use snap-fit structures without metal screws
    - Face-contact terminal block design

3. Meeting Conclusions The "Grid Gateway Meter Performance Test Report" demonstrated that this particular gateway meter model exhibits excellent metering characteristics across full-range current measurement and 0-360° phase angles, serving as a reference for domestic high-end meter design and development. In this regard, Wasion's published papers "Application of Composite Newton-Cotes Integration Algorithm in Electric Energy Metering" and "A High-Precision Dynamic Phase Angle Error Compensation Algorithm" provide valuable experience for flattening basic metering error curves and controlling metering errors at extremely low power factors.

II. Deepening Application Research on Electronic Meter Reliability Technology

1. Chongqing Electric Power Research Institute: "Research Progress on Smart Meter Reliability Technology"

1) Currently, the IEC62059-41 standard commonly used in China provides guidance for meter reliability prediction work, but obtaining basic failure rates for various components presents significant challenges. The basic failure rates provided in GJB/Z299C represent generic failure rates based on component categories, lacking credibility.

2) Considering the poor operability of IEC62059, Chongqing EPRI proposed a simplified reliability assessment test method: selecting only 1 of the 5 environmental stress groups specified in IEC62059 (75°C temperature, 85% humidity); additionally applying electrical stress conditions during testing including varying voltage/current (in stages), short-term overvoltage and power interruptions (30 cycles), harmonic loads (applied in stages), and communications. Test duration is controlled at 45 days.

2. Wasion Group: Introduction to IEC61709-2011 Standard "Reference Conditions for Electrical Components Reliability Data for Conversion of Stress Levels and Derating" Compared with China's GJB/Z299C "Electronic Equipment Reliability Prediction Manual" or the U.S. Military Handbook (MIL-HDBK-217F), the IEC61709 standard offers stronger guidance and universality.

3. Meeting Conclusions This meeting marked the first time in China's meter industry that IEC61709-2011 was interpreted and domestic smart meter reliability technology research progress was presented:

1) Verification shows that GB/T 17215.941-2012/IEC62059-41:2006 focuses on: first, the stress model for smart meter reliability prediction—that is, the component stress model for converting failure rates under reference conditions to failure rates under operating conditions—primarily referencing IEC61709; and second, component failure rate data, with reference data manuals mainly including Siemens specification SN29500 component failure rates and IEC62380-2004 reliability data handbook (generic model for reliability prediction of electronic assemblies, PCBs, and equipment). This demonstrates that a relatively complete series of international standards for meter reliability prediction has been formed.

It is understood that current domestic smart meter reliability prediction application research primarily references GB/T 17215.941-2012/IEC62059-41:1996 and GJB/Z299C, whose combined application level still shows significant gaps compared with international meter reliability prediction standard series.

4. Schwyzer Company (Wasion-Siemens Joint Venture): "Siemens: Overview of Component Failure Rate Prediction Standard SN29500"

1) SN29500 is an internal standard established by Siemens in 1978 that proposes component failure rate predictions for telecommunications and wireless communication systems. This standard provides foundational data for developing EN/IEC61709 standards.

2) SN29500 comprises general provisions, integrated circuits, discrete semiconductors, passive components, electrical connections, electrical and optical connectors and sockets, relays, switches and pushbuttons, signals and indicators, contacts, semiconductor signal receivers, [light-emitting diodes (LED), infrared-emitting diodes (IRED) and semiconductor lasers], optocouplers, and baffles.

3) **Failure rate (λ):** The cumulative number of non-repairable failures occurring within a given time interval, measured in FIT (Failures in Time, 10^{-9} failures/hour). Component failure rates are calculated by multiplying the failure rate under reference conditions by voltage, current, and temperature relationship factors, with these parameters stored in list form in the SN29500 information database. SN29500 also provides calculation formulas for voltage and current relationship factors. Product failure rates are obtained by summing individual component failure rates in series.

4) **Reliability R(t):** The probability of product functional integrity after operating for a certain time:
   R(t) = e^(-λt)
   SN29500 provides correspondence tables between product reliability and operating time (hours). For example, a product reliability decreasing to 97% corresponds to 15.3184 years of operation.

Note: According to Chint Instrument & Meter Company's paper "DDZY666 Smart Meter Reliability Design," IEC62059-41 is currently the international standard specifically for electricity meter reliability, with its stress data sourced from Siemens SN29500 standard. SN29500 is specifically designed for industrial, medical, and civil electronic products, updated every two years with relatively reliable data. OFGEM (UK Gas and Electricity Markets Authority) currently uses SN29500 for electricity meter reliability assessment.

Smart meters often use specially commissioned custom components such as housings and hardware, LCD displays, and lithium batteries. Parameters for these components may not be found in the SN29500 standard and require separate rigorous and cautious treatment.

5. Meeting Conclusions

1) Siemens' SN29500 is an internationally widely applied standard for component failure rates in industrial, medical, and civil electrical/electronic

products. This meeting marked the first time in China to propose in-depth research and application of the SN29500 standard, aiming to promote implementation of IEC62059-11/21/31/41/51 and corresponding international "Electricity Metering Equipment—Dependability" standards. The goal is to help meter enterprises/departments establish a relatively complete electricity meter reliability technology system, adapt to State Grid's strict smart meter quality control requirements, and enhance the international competitiveness of exported meters. To this end, the meeting recommended that Chongqing EPRI and Wasion Group focus on the following projects in SN29500 application research:

- Collect and translate international standards referenced by IEC62059 in the reliability field (12 items), particularly SN29500 and IEC61709 standards.
- Accelerate construction of failure rate databases for smart meter and terminal components. Use SN29500 as the baseline to establish graded databases for domestic/imported component failure rates.
- Conduct comparative research on multiple methods for smart meter reliability prediction and verification testing based on practical and credible principles to select typical methods.
- Study and plot reliability versus service life curves/tables for smart meters based on actual domestic grid requirements to provide basis for smart meter service life assessment.
- Use counter-evidence methods to conduct reliability level testing and comparison between imported high-end meters and domestic counterparts, with specific methods to be studied separately.
- Research and propose the architecture and content of a Chinese meter enterprise electricity meter reliability technology system, referencing Landis+Gyr's meter reliability standard system (ALEG).

III. Expansion of Three-Phase Multifunction Meter Software Testing Technology

1. Wasion Group: "Smart Meter Software Testing Technology" Gray-box testing of meter software is a verification method 介于 between black-box and white-box testing. Wasion has independently developed a fault injection test device for gray-box testing to simulate field conditions where meters experience strong radiation and interference causing MCU abnormal resets. The exploration is ongoing: for example, errors, interruptions, and recovery of clock/measurement chip data lines; analog variation and interruption/recovery of clock battery/external battery voltage; interference and simulation of meter power-on and reset signals.

Since these methods are closely related to circuit design and lack universality among manufacturers—for instance, SOC integration of measurement and clock functions eliminates external lines.

2. Meeting Conclusions Smart meter software testing is a key focus and also a difficult point in State Grid's smart meter quality assurance measures research, primarily due to the lack of unified testing and evaluation methods. The meeting expects Wasion to summarize years of field fault handling experience, analyze common and unique cases, and propose more comprehensive gray-box testing technology for meter software. Meanwhile, the meeting will facilitate exchanges on smart meter and meter reading network software architecture design and evaluation within this collaborative research framework, aiming to elevate the development and application level of domestic smart meter software.

IV. Reference Documents

1. Wasion Group: "Research on Metering Stability of Grid Gateway Meters" Metering stability is the probability that a grid gateway meter maintains measurement accuracy within allowable limits under certain conditions—an extension of meter reliability and one of the most important metering assessment indicators.

Design approach for grid gateway meter metering stability:

1) **Voltage and current sampling circuit stability analysis:**
    - Filter circuit resistor stability should receive equal attention as sampling resistor stability for ADC input signals.
    - Series and parallel resistors in voltage sampling circuits should use resistors of the same material, manufacturer, and formulation.
    - Stability of voltage divider resistors at current sampling output directly affects current sampling stability.
    - Current transformer (CT) accelerated stress tests reveal that larger primary sampling resistors configured for the same CT result in proportionally larger post-test error changes.
    - Thick-film resistors are unsuitable for sampling circuit components.
    - Lower film temperature in thin-film resistors results in smaller resistance variation over time, ensuring at least 30% temperature margin for gateway meters under extreme operating conditions.
    - Resistance values gradually increase over time.
2) **Verification of critical metering components:**

- Targeted verification testing based on analysis of grid gateway meter metering error composition and stability objectives.

- Components affecting metering error stability include: ADC, reference voltage, current sampling resistors, voltage divider resistors, RC circuit resistors, RC circuit capacitors, and printed circuit boards.

- Accelerated reliability testing of meters is applicable to grid gateway meter metering stability analysis.

- Case study: Selected resistor high-temperature life testing and humidity resistance testing methods (details omitted).

3) **Production process design:**
   - **Flux residue control:** For Wasion MA2 meters, the entire assembly process (SMT, wave soldering, manual soldering) controls board surface residue to <10 g NaCl/sq, with effective protection through automatic conformal coating.

   - **Burn-in screening:** The time meters spend in production workshops belongs to the early failure period; burn-in time is extended accordingly. Wasion MA2 meters undergo 20 days of high-load burn-in, with accuracy rechecked before shipment.
4) **Metering stability verification:**
   - Borrowing reliability research methods of applying external stresses for accelerated testing to verify metering stability.

   - Case study: 2000h/70°C/95% humidity high-temperature high-humidity verification of Wasion MA2 meter error curve (details omitted).

   - Wasion MA2 grid gateway meters have demonstrated exceptionally high metering stability through field trial installation, long-term simulated operation, 2000h high-temperature high-humidity impact testing, and electrical stress impact testing.
5) **It is reasonable to define grid gateway meter metering stability as maintaining measurement accuracy within 50% of the 0.2S class precision requirement.**

2. Jiangsu Electric Power Research Institute & Wasion Group: "White-Box Testing of Smart Meters Based on EEPROM Data Read/Write"

3. Chongqing Electric Power Research Institute & Wasion Group: "Smart Meter Software Quality Evaluation Based on Analytic Hierarchy Process" This paper describes the recent two-year research on performance differences and testing between domestic and imported high-end meters conducted by the "China Modern Grid Measurement Technology Collaborative Research Platform" initiated and organized by the authors. The reference documents supplement the main content, sourced from papers published by Wasion Group and Chongqing Electric Power Research Institute in professional journals. Next steps will continue to deepen collaborative exploration in this area:

1) **Further research on grid gateway master meter performance testing technology:**
    - Metering performance testing technology, primarily metering stability assessment methods, including quantitative testing of extremely low-load metering errors and meter combination error testing according to IR46 requirements.
    - Meter reliability technology using IEC61709 and SN29500 standards for reliability prediction research and application.
    - Research on design characteristics of imported high-end meters.
2) **Given that IEC has not yet established standards for high-quality three-phase multifunction meters, it is recommended that provincial grid EPRI, major meter enterprises, and the authors collaborate to propose practical technical requirements for grid gateway metering master meters, referencing the quality level of imported high-end meters.**
3) **Advocate for the meter industry to develop toward high-end metering, with both major meter enterprises and grid authorities demonstrating industry responsibility. Major enterprises should increase development talent and funding for grid gateway metering master meters to produce domestic high-end meters meeting international quality standards. Grid authorities should arrange parallel operation of domestic and imported high-end meters for comparative testing, assessment, and technical improvement. The expectation is for domestic high-end meters to achieve master meter status for grid gateway metering at an early date.**

References:

[1] Yang Cuifang. Development and Application of DT/SSD205 Three-Phase Electronic Multifunction Watt-Hour Meter in Electric Energy Metering. *Science & Technology Information*, 2012-12-05.

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