Practicality Evaluation of Multifunctional Electric Energy Meter Standards

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Abstract

This paper conducts a practical evaluation of standards for multifunction electricity meters, particularly through a comparative analysis of International Electrotechnical Commission (IEC) standards and relevant domestic standards. Through in-depth examination of the standards, this study attempts to reveal their advantages and disadvantages in practical applications, and explores ways to further refine the standards to better guide the design, production, and application of multifunction electricity meters.

Full Text

Evaluation of the Practicality of Multi-Function Energy Meter Standards

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Abstract: This paper evaluates the practicality of relevant standards for multi-function energy meters, with particular focus on comparative analysis between International Electrotechnical Commission (IEC) standards and domestic Chinese standards. Through in-depth examination of these standards, this study aims to reveal their respective advantages and disadvantages in practical applications, and discusses approaches to further improve the standards to better guide the design, production, and application of multi-function energy meters.

Keywords: multi-function energy meter; standard; practicality evaluation

1. IEC Relevant Standards

Currently, IEC has not established dedicated standards specifically for multi-function meters. The relevant standards include IEC 62052-11, IEC 62053-21/22/23. IEC 62052-11 covers general requirements for static electricity meters, including terminology and definitions, standard electricity values, mechanical requirements, climatic conditions, and electrical requirements (including electromagnetic compatibility). IEC 62053-21/22/23 address particular requirements for static meters for active energy classes 1 and 2, active energy classes 0.2S and 0.5S, and reactive energy classes 2 and 3, respectively, covering special electrical requirements, accuracy requirements, and test methods.

For multi-energy meters that incorporate additional functional elements—such as maximum demand indicators, electronic tariff registers, time switches, ripple control receivers, and data communication interfaces—within the same enclosure, the standards applicable to these functional elements also apply. To ensure the inherent functionality of meters under nominal operating conditions, test levels are established as minimum values. For special applications, other test levels may be required and shall be determined through negotiation between user and manufacturer.

The accuracy application range for energy measurement includes: (a) active energy measurement: $\cos\phi = 0.25(L)$-1-0.5(C); (b) reactive energy measurement: $\sin\phi = 0.25(L/C)$-1. Specific error limits are defined for different accuracy classes. For IEC 62053-21:2003 (Classes 1 and 2 static active energy meters), when $\cos\phi = 0.5(L)$, the error limit is 1% for Class 1 and 2% for Class 2; when $\cos\phi = 0.25(L)$, the error limit is 3.5% for Class 1 (Class 2 not specified). For IEC 62053-22:2003 (Classes 0.2S and 0.5S static active energy meters), when $\cos\phi = 0.5(L)$, the error limit is 0.3% for Class 0.2S and 0.6% for Class 0.5S; when $\cos\phi = 0.25(L)$, the error limit is 0.5% for Class 0.2S and 1% for Class 0.5S. For IEC 62053-23:2003 (Classes 2 and 3 static reactive energy meters), when $\sin\phi = 0.5(L)$, the error limit is 2% for Class 2 and 3% for Class 3; when $\sin\phi = 0.25(L)$, the error limit is 2.5% for Class 2 and 4% for Class 3.

Several issues arise from these standards. First, when $\cos\phi$ (or $\sin\phi$) $\neq 1$, the degree of error limit relaxation varies and is stricter than early international general requirements based on the ratio of error limit at $\cos\phi = 1$ to $\cos\phi$. Second, for $\cos\phi < 0.25$, should error limits be determined by enterprise standards? Third, what are the error definition and calculation method when $\cos\phi = 0$?

Regarding voltage circuit power consumption, when switching power supplies are used, the peak power consumption of the voltage circuit may exceed the average value, but must ensure that the voltage transformer connected to the meter has sufficient load capacity. For meters containing internal transformers, manufacturers should specify whether the load is inductive or capacitive. This raises questions about: (1) what types of switching power supplies are commonly used in meters and what product standards apply, and (2) how to capture peak power consumption of switching power supplies.

The average temperature coefficient should be measured across the entire operating range. Apparent energy measurement requirements remain to be investigated. The standard for energy meter test equipment is IEC 60736:1982, while reliability requirements are covered by the IEC 62059 series standards.

These IEC standards raise several considerations. First, new requirements and test methods in updated IEC versions should be tracked and adopted by domestic manufacturers to improve product quality. Second, existing requirements and test methods in IEC standards that are unclear need technical improvements. Third, discrepancies between IEC standards and current product design technologies require supplementary and extended technical requirements and test methods.

Additional technical issues include: the design of test equipment for generating external constant magnetic fields; test methods for newly specified reference conditions; waveform compliance testing; optical test outputs; external continuous magnetic flux density; reference frequency external magnetic flux density; verification of rise time using Tr = 0.2 s standard receiving diodes; testing of light radiation intensity Er signals; high-frequency electromagnetic fields from 30 kHz to 2 GHz; conducted disturbances from radio frequency fields from 150 kHz to 80 MHz; requirements for electromagnetic compatibility (EMC) testing; design accuracy indicators for test circuits; measurement of active energy true values containing harmonics (fundamental + harmonics) by standard meters; measurement of total active energy (fundamental + harmonics) by standard meters under sub-harmonic conditions; and the need for harmonic analysis technology beyond the 21st harmonic (international practice uses 63rd harmonic analysis).

For voltage ranges, performance must be determined under specified operating range, extended operating range, limit operating range, and maximum voltage during ground faults, requiring metrological traceability of standard meters. Electrical/optical test outputs follow IEC 62053-31. During electrostatic discharge, radiated electromagnetic field, and surge immunity tests, temporary reduction or loss of function and performance is permissible. During fast transient burst tests, temporary reduction or loss of function and performance is also permissible, though meter accuracy must remain within limits specified in relevant standards, verifiable through counting methods or other appropriate means. During radio frequency field-induced conducted disturbances and damped oscillatory wave immunity tests, equipment condition must not be disturbed and error changes must remain within specified limits.

The current circuit power consumption index for static reactive meters is 5 VA for both Class 2 and Class 3. When testing three-phase reactive energy meters, if the test method and meter under test are affected by voltage and current imbalance to different degrees, errors may increase. In such cases, the reference voltage must be adjusted to achieve perfect symmetry. This raises questions about: (1) what measurement principles are commonly used in static reactive meters, and (2) how voltage imbalance affects sine-type reactive meters.

2. GB/T 17215.301-200X

GB/T 17215.301-200X is the first Chinese national standard specifically addressing special requirements for multi-function meters. Based on advanced international standards, it establishes special technical specifications for multi-function meters. However, it lacks supplementary technical requirements for application issues existing in IEC standards, holds different views on demand accuracy, and requires subsequent verification methods for apparent energy measurement accuracy, event recording, and extended functions.

The standard is a product specification that reflects most requirements of product ordering technical specifications. Its provisions for standard electricity values, mechanical requirements, climatic conditions, electrical requirements, and EMC and test methods directly reference IEC 62052-11. The energy measurement unit portion must comply with corresponding national standards for electricity meters (GB/T 17882, GB/T 17883, GB/T 17215). The multi-function meter national standard only specifies special requirements for electricity meters.

The standard defines technical requirements for energy measurement, basic functional requirements, additional functions, display requirements, programming requirements, and safety and software requirements. It proposes Class 2 accuracy for apparent energy measurement and requires that demand measurement accuracy comply with requirements for the corresponding active energy measurement accuracy class index. It explicitly lists event recording and extended functions, standardizes demand period algorithms, and specifies voltage range test methods. The standard adopts IEC 62056-61 for meter identification and proposes determining meter constants at 1% Ib (In) with $\cos\phi = 1$. Software functions include dual backup data areas with checksum technology, sealable buttons and built-in switches, and hierarchical access privilege management. Reliability verification tests are conducted according to JB/T 50070.

3. National Metrological Verification Regulation: JJG 596-1999

The role of legal metrological verification is to ensure measurement accuracy and value consistency of measuring instruments. JJG 596-1999 provides basic content for metrological verification, including technical requirements for meters under test, basic verification conditions, requirements for verification equipment, verification methods, verification connection diagrams, data rounding methods, and verification result processing.

This regulation applies to verification of AC active energy meters (including standard energy meters and installed meters). Test current is represented by Ib without distinguishing between directly connected meters and transformer-connected meters. It proposes methods for determining basic error tests, methods for checking register readings, permissible errors for verification equipment, and permissible standard deviation estimates S(%). The regulation reduces meter power consumption indicators, proposes acceptance error limit requirements and error consistency assessment, and redefines disputed common terms including voltage loss, critical voltage, phase failure, and current loss. It improves the demand accuracy calculation method specified in DL/T 614-1997, proposes meter constant calculation formulas and structural requirements, and conducts protocol compliance testing and data transmission line anti-interference tests according to DL/T 645-2007. Reliability testing follows DL/T 830-2002.

Measurement repeatability of electronic energy meters is characterized by standard deviation estimate S(%), with corresponding calculation formulas proposed. The creep test method specifies that with reference voltage applied to the voltage circuit and no current in the current circuit, the meter should produce no more than one pulse within 10 times the time required to produce one pulse at starting current. Methods for determining demand error (%) are proposed; demand error (%) should not exceed the accuracy class specified for the energy meter, and demand period error should not exceed 1% of the demand period.

4. Electric Power Industry Standard: DL/T 614-2007

DL/T 614-2007 specifies technical elements for ordering, acceptance, and use of multi-function energy meters, and standardizes function settings. For directly connected meters, it recommends selecting meters with overload capacity of 10 times or more . The standard references IEEE 1459-2000 "Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions."

Unlike DL/T 614-1997, DL/T 614-2007 is positioned as an electric power industry technical specification for energy meter applications. It improves demand accuracy calculation methods, proposes assessment of meter error consistency and DL/T 645-2007 protocol compliance testing, and for the first time in China references IEEE 1459-2000. As an electric power industry standard, it needs to align with modern power grid development and promote new energy measurement technologies, including harmonic energy measurement, power quality monitoring, and application and testing of communication methods.

5. Synthesis and Recommendations for Enterprise Standards

Based on the development of domestic new multi-function meter products, the industry expects IEC to introduce new measurement standards including: (1) Class 0.1S active energy measurement, (2) Class 0.2S/0.5S reactive energy measurement, (3) Class 0.3S/1 apparent energy measurement, (4) test methods for harmonic influence quantities with uncertainty calculations, and (5) definitions of harmonic power and harmonic analysis calculation methods.

Currently, we cannot expect a unified international standard encompassing modern multi-function energy meter measurement, functional requirements, and test methods. New multi-function meters, as high-quality products, require advanced, reasonable, and complete enterprise standards. Such standards should: (a) adopt current reference standards including newly proposed requirements and test methods, and establish missing technical requirements and test methods; (b) adopt component-related standards; (c) reference international and domestic product performance and technologies; (d) incorporate grid-required measurement application technologies; (e) include software and reliability design; and (f) address metrological traceability technology.

When developing enterprise standards for new multi-function meters, the following measurement requirements and reference documents should be considered:

a. Comprehensive requirements including standard electricity values, mechanical requirements, electrical requirements, climatic conditions, basic functional requirements, additional functions, display requirements, programming requirements, and safety and software requirements: GB/T 17215.211-2006, GB/T 17215.301-200X (mechanical test, climatic condition test, and electrical test reference standards omitted).

b. Energy measurement accuracy: - Class 0.2S–1 active energy measurement: IEC 62053-21/22, DL/T 614-2007 - Class 2–3 reactive energy measurement: IEC 62053-23 - Class 0.1S grid gateway meters: reference Q1000 enterprise standard - Active (reactive) measurement when $\cos\phi(\sin\phi) = 0$–0.25: to be investigated - Apparent energy measurement: to be investigated

c. Energy measurement chips: dedicated metering chips for meter enterprises/general chip combinations with dedicated algorithms/general three-phase SOC metering chips.

d. Multi-tariff measurement: GB/T 15284-2002

e. Maximum demand measurement: GB/T 17215.301-200X, DL/T 614-2007

f. Prepayment measurement: GB/T 18460.3-2001

g. Time switch: GB/T 9092-1998, IEC 61038-1998

h. Voltage loss timer: DL/T 566-95

i. Harmonic power definition: IEEE 1459-2000, GB/T 19862-2005, DL/T XXX-XXXX

l. Harmonic and inter-harmonic measurement requirements: GB/T 17626.7-1998

n. Pulse output devices: IEC 62053-31:1998

o. Meter power consumption: IEC 62053-61:1998

p. LCD testing: to be investigated

q. RS485 testing: to be investigated

r. Infrared modulated optical communication: DL/T 645-2007

s. Data exchange protocols: DL/T 645-2007 with special test software compiled by grid metrology authorities; IEC 62056 with CTT 2.0 DLMS/COSEM conformance test tool CTT.

t. Electromagnetic compatibility (EMC): GB/T 17626.2-1998, GB/T 17626.3-2002, GB/T 17626.4-1998, GB/T 17626.5-1998, GB/T 17626.6-1998, GB/T 17626.10-1998, GB/T 17626.11-1999, GB/T 17626.12-1998, GB 9254-1998

u. Reliability: IEC 62059-11:2002, IEC 62059-21:2002, DL/T 830-2002, JB/T 6214-92, JB/T 50070, DL/T 614-2007, multi-function meter type approval outline

v. Multi-function meter performance evaluation (quality) test methods (to be developed subsequently)

Conclusion

Through this practicality evaluation of multi-function energy meter standards, this paper reveals the advantages and disadvantages of current standards in practical application and proposes corresponding improvement recommendations. In the future, as power systems continue to develop and smart grid construction advances, application scenarios for multi-function energy meters will become increasingly complex and diverse. Therefore, continuous improvement and optimization of relevant standards are necessary to better adapt to practical application requirements and promote innovation and development of multi-function energy meter technology. Simultaneously, we should strengthen exchanges and cooperation with the international electrical engineering community, draw upon advanced international experience and technical achievements, and promote the internationalization of domestic multi-function energy meter standards. Through joint efforts, we believe we can drive continuous progress in multi-function energy meter technology, providing strong support for safe, stable operation of power systems and smart grid construction.

References

[1] Zhang Zhen. Evaluation of the Practicality of Multi-Function Energy Meter Standards.

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