Promoting User Reactive Power Energy Metering Management and the Development and Application of Fundamental Wave Reactive Energy Meters

Authors: Zhang Chunhui, Zhang Zhen, Zhang Zhen

Date: 2024-01-23T00:00:00+00:00

Abstract

The article primarily introduces the development of reactive energy metering technology in China, involving several technical issues concerning reactive energy meters. The non-fundamental harmonic components in sinusoidal reactive power are becoming increasingly prevalent; however, the reactive power standard should refer to fundamental reactive power. The article also addresses practical problems in domestic reactive energy metering technology, such as the increase in non-fundamental reactive power components caused by the application of power electronic devices, as well as issues concerning the metrological verification of reactive energy meters and the grid access control of power electronic equipment.

Full Text

Preamble

Promoting User Reactive Energy Metering Management and the Development and Application of Fundamental Reactive Energy Meters

ZHANG Chunhui[1], **ZHANG Zhen**[2]
(1. State Grid Shandong Electric Power Company, Jinan, Shandong 250100, China;
2. Huaneng Jinan Huangtai Power Generation Co., Ltd., Jinan, Shandong 250100, China)

Abstract: This paper examines the evolution of reactive energy metering technology in China, addressing key technical challenges associated with reactive energy meters. With increasing non-fundamental components in sinusoidal reactive power, the reactive power standard should refer specifically to fundamental

reactive power. The discussion encompasses practical domestic issues in reactive energy metering, including the rise of non-fundamental reactive power components due to power electronic devices, as well as challenges in reactive energy meter calibration and grid-entry regulation of power electronic equipment.

Keywords: reactive energy metering, fundamental reactive energy meter

At a recent forum on modern grid measurement technology in China, participants discussed the development of domestic reactive energy metering technology, raising an important question: Why have domestic fundamental reactive energy meters failed to gain traction?

1. Industry Expert Perspectives (October 3, 2021)

Industry experts shared their views on the development of domestic reactive energy metering technology:

The composition of sinusoidal reactive power is changing. With the proliferation of power electronic devices, non-fundamental components in sinusoidal reactive power are increasing. However, the reactive power standard should refer to fundamental reactive power, as specified in GB/T 17215.323-2008 and GB/T 17215.324-2017. Unfortunately, most single-phase meters currently measure "full-wave" reactive power rather than fundamental reactive power.

Researchers focused on harmonic mitigation equipment tend to study "harmonic reactive power" for control purposes, such as Wang Zhao'an from Xi'an Jiaotong University. However, for distribution network and end-user operational safety, fundamental reactive power should be the primary consideration. For example, LED display screens (commercial billboards in residential areas) commonly use switching power supplies without Power Factor Correction (PFC) functionality due to cost considerations. Similarly, household LED lights lack PFC, while LED lights exported to Europe include this feature.

2. Author's Analysis: Key Issues in Reactive Energy Metering

The authors identify several critical problems requiring investigation:

Increasing Non-Fundamental Reactive Power Components: The widespread application of power electronic devices has led to a growing proportion of non-fundamental reactive power components in the grid.

Reactive Energy Meter Calibration Challenges: While GB/T 17215.324-2017 specifies fundamental reactive power as the standard, most single-phase meters measure full-wave reactive power. This discrepancy creates calibration and standardization issues.

Grid-Entry Regulation of Power Electronic Devices: Domestic LED advertising screens and household LED lighting typically lack PFC functionality, whereas European exports must include it. This highlights a regulatory gap in China.

3. Management of User Reactive Energy Metering and Legal Verification

Grid management of reactive energy metering is divided into two categories: grid-internal metering and user metering. While reactive metering points are proposed by distribution and marketing departments, the ordering, verification, installation, operation, and maintenance of reactive energy meters are centrally managed by grid metering departments.

Since grid-internal reactive energy meters are primarily used for technical and economic performance evaluation, this paper focuses on user reactive energy metering management and legal verification procedures.

State Grid User Statistics (2021)

In 2021, State Grid's service area encompassed 520 million users: - Single-phase users: approximately 91% of total (473 million households) - Three-phase users: 9% of total (47 million households)

1) Grid Focus on High-Capacity Users

According to the "Power Factor Adjustment Electricity Tariff Method" issued by the former Ministry of Water Resources and Electric Power and the State Price Bureau, users with relatively large capacity (approximately 50 kVA and above) are subject to power factor adjustment tariffs and must install reactive energy meters. Specifically:

- Among three-phase meters, high-voltage three-phase multifunctional meters (approximately 4.7 million units) and low-voltage three-phase multifunctional meters for large-capacity users (50 kVA and above, approximately 12 million units) totaling 16.7 million units (35.5% of all three-phase meters) feature reactive energy metering functionality.
- Single-phase users and low-voltage three-phase users with smaller capacity (below 50 kVA, approximately 30.3 million households) only have active energy meters installed, with their reactive energy consumption unmeasured. For exceptionally large single-phase users, single-phase multifunctional meters with reactive energy metering capability may be installed.

Limitation of Current Practice: The policy of not installing reactive energy meters for single-phase users and small-capacity three-phase users has significant drawbacks: it prevents monitoring of reactive power flow, reactive power balance, and distributed reactive compensation in low-voltage networks, leading to increased line losses and difficulties in segment loss analysis.

2) Power Factor Calculation for Three-Phase Users

Sinusoidal Load Conditions: For sinusoidal loads, user power factor is calculated as: Active Energy / $\sqrt{}$(Active Energy^2 + Reactive Energy^2), using the root-sum-square algorithm for apparent energy based on active and reactive energy measurements.

Non-Sinusoidal Load Conditions: For non-sinusoidal loads, VA-based algorithms should be used for apparent energy in power factor calculations. However, current grid marketing departments continue to use the sinusoidal root-sum-square method, which is technically inappropriate for modern load profiles.

3) National Reactive Energy Measurement Standards Under Development

China National Institute of Metrology (NIM): According to Dr. Lu Zuliang from NIM, the power frequency reactive power standard was designed as a metrological function of the power frequency harmonic power standard device established by NIM in 2006. Following international comparison, the expanded uncertainty of this power frequency reactive power standard reached 20×10^{-6}, recognized by the International Bureau of Weights and Measures and published on its website.

Dr. Lu's report "Research on Power Frequency Harmonic Power Standards" documents that compared with the national single-phase energy reference standard (expanded uncertainty of $\pm15\times10^{-6}$), *the power frequency harmonic power standard device (including the reactive power standar*
6}$ - At fundamental 90° (capacitive): difference of 9.8 (W/VA), i.e., 9.8×10^{-6}

China Electric Power Research Institute (CEPRI): In 2010, CEPRI completed development of a sinusoidal reactive power measurement standard device for the second time. This device employs a current comparator-based capacitance bridge structure to obtain pure, stable quadrature current at power frequency, achieving accurate measurement of sinusoidal power frequency reactive power through traceability to basic electrical parameters including DC voltage, resistance, and capacitance.

In the same year, CEPRI conducted a value comparison with NIM's power frequency reactive power measurement standard, achieving an expanded uncertainty of 30×10^{-6} (K=2) for CEPRI's device. Whether CEPRI's power frequency reactive measurement standard has completed establishment, assessment, and certification requires further verification.

4) Two-Tier Legal Verification System for Reactive Energy Meters

National Verification Regulations: The national metrological verification regulation for reactive energy meters has not yet been released. Its publication and implementation will likely await completion of the national power frequency reactive reference standard establishment and assessment.

Current Provincial Reference Standard: JJG(Zhejiang) 109-2010 "Verification Regulation for Electronic Reactive Energy Meters" serves as a provincial local standard. This regulation was developed with reference to JJF1245.5-2010

"Program of Pattern Evaluation for Installed Meters - Particular Requirements - Static Meters for Reactive Energy (Classes 2 and 3)."

Related national standards include: - GB/T 17215.323-2008: Particular requirements for static meters for reactive energy (Classes 2 and 3) - GB/T 17215.324-2017: Particular requirements for static meters for reactive energy at fundamental frequency (Classes 0.5S, 1S, and 1)

Analysis reveals that JJG(Zhejiang) 109-2010 is an early verification regulation applicable only to static reactive energy meters produced according to GB/T 17215.323-2008, and not suitable for fundamental reactive energy meters produced under GB/T 17215.324-2017.

Consequently, most single-phase meters currently measure full-wave reactive energy, and no fundamental reactive energy meter products are observed in the market. This is because while national standards for fundamental reactive energy meters exist, corresponding verification regulations have not kept pace, and grid metering departments have not generated market demand.

5) Grid-Entry Testing and Licensing of Power Electronic Devices

With the rapid growth of electronic components and equipment in modern industrial production and daily life, electrical and electromagnetic disturbances (including conducted and radiated EMI and electrostatic discharge) increasingly cause malfunctions and damage to electrical and electronic equipment. In response:

International Standards: European and American countries established early research on grid-entry testing and licensing procedures for power electronic devices, developing comprehensive international standards for testing and suppressing electromagnetic disturbance effects, primarily: - IEC 61000 series: Electromagnetic compatibility (EMC) testing and measurement techniques - IEEE 1459-2010: IEEE Standard for definitions of electrical power quantities under sinusoidal, non-sinusoidal, balanced, or unbalanced conditions

Domestic Standards: China's EMC standards (GB/T 17626 series) are equivalent to IEC 61000. GB/T 14549-93 "Harmonics in Public Supply Network" was published in 1993, but IEEE 1459-2010 has not yet been adopted domestically.

Grid-Entry Testing and Licensing in China: - For high-voltage harmonic source users, grid connection design reviews typically include harmonic mitigation requirements. - For low-voltage users' power electronic equipment, grid-entry testing and licensing requirements (including PFC application) have not been formally issued by grid authorities. This reflects a long-standing weakness in low-voltage grid management, with unclear responsibilities between distribution and marketing departments. - For metering, electromagnetic disturbances from power electronic devices primarily cause static energy meter errors and degrade local PLC communication quality in electricity information acquisition systems. Grid metering departments must therefore monitor power electronic device grid entry, conduct electromagnetic disturbance testing and suppression research, and develop full-wave, fundamental, and non-fundamental reactive energy metering technologies, as well as study high-frequency and transient electromagnetic disturbance impacts on PLC communication quality.

Recommendations for Developing Domestic Fundamental Reactive Energy Meters

Pending completion of the national reactive energy reference standard establishment and national verification regulation publication, the authors recommend that State Grid and provincial metrology administrative departments adopt the following measures to promote development and application of domestic fundamental reactive energy meters:

- **State Grid:** Establish and assess the highest working standard for reactive energy metering—handled by China Electric Power Research Institute.
- **Verification Regulations:** Develop verification regulations for both full-wave and fundamental reactive energy meters—handled by provincial metrology administrative departments.
- **Enterprise Standards:** Include fundamental reactive energy metering functionality in State Grid's new generation smart meter enterprise standards—handled by State Grid metering management departments.
- **Procurement:** Include new generation smart meters with fundamental reactive energy metering functionality in State Grid's annual smart meter bidding plan and implement procurement—handled by State Grid metering management and materials management departments according to their respective responsibilities.

References

[1] JJF1245.5-2010 "Program of Pattern Evaluation for Installed Meters - Particular Requirements - Static Meters for Reactive Energy (Classes 2 and 3)"

Author Biographies:
ZHANG Chunhui (male, born 1938) specializes in electric energy metering technology research.
Corresponding Author: ZHANG Zhen (male, born 1977) specializes in electric energy metering technology research.

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