Discussion on Canada's Adoption of Fundamental Active Power Measurement in the Application Research of Domestic High-End Electricity Meters

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Abstract

This paper presents an overview of Canada's adoption of fundamental active power for energy metering and the issues raised in expert discussions. All meters installed in Canada in 2021 utilized fundamental power for energy metering, which has attracted international attention. Expert discussions encompassed topics including the direction of harmonic active power, differing perspectives on fundamental metering, harmonics generated by electronic switching devices, the rationality of fundamental active power metering, and the applicability of harmonic load power algorithms. The author contends that adopting fundamental metering for active energy represents a compromise metering scheme that is beneficial to both the power grid and end-users. The domestic electricity meter industry should conduct step-by-step research and draw upon Canada's experience, and revise the IEC standards or national standards for active energy meters to explicitly specify fundamental active power metering.

Full Text

Discussion on the Use of Fundamental Active Power Measurement in Canada in the Application Research of Domestic High-End Electricity Meters

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Abstract: This paper introduces the overview of Canada's adoption of fundamental active power for electric energy metering and the issues raised in expert discussions. Canada's decision to use fundamental power for all meters installed in 2021 has attracted international attention. Expert discussions have addressed topics including the direction of harmonic active power, differing perspectives on fundamental power metering, harmonics generated by electronic switching devices, the rationality of fundamental active power metering, and the applicability of algorithms for harmonic load power calculation. The authors argue that adopting fundamental active power metering represents a compromise metering scheme that benefits both the grid and end users. China's metering industry needs to gradually study and reference Canada's experience, and revise IEC standards or national standards for active power meters to explicitly include fundamental active power metering.

Keywords: fundamental active power measurement, electric energy metering

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Evolution of Grid Energy Metering Points and Meter Selection

Electricity meters are primarily used for metering grid power supply and sales, with metering points distributed across vast geographical areas. As grid technology has upgraded and transformed, the role of electricity metering has continuously expanded and evolved.

Sales Metering Evolution: In traditional grids, sales metering points positioned electricity meters at the connection node between distribution networks and end users, serving as distribution terminals responsible for power trade settlement metering. Starting in 2009 with smart grids, these metering points became intermediate nodes between distribution networks and users. In addition to trade settlement, they gained advanced interactive functions between distribution networks and users. By 2019, with the State Grid's Ubiquitous Electric Power Internet of Things (including distribution IoT), metering points further evolved into intermediate nodes with added capabilities for ubiquitous connectivity and holographic perception, extending the IoT to the user side.

Supply Metering and Line Loss Calculation: Grid total supply volume is aggregated from metering points at power plant grid connections and inter-grid power exchange points. The difference between total supply and total sales volumes enables calculation of grid line loss rates. Similarly, the difference between supply and receiving-end metering points on high-voltage lines yields high-voltage line loss rates, while the difference between low-voltage distribution transformer area master meters and the sum of user meters within that area calculates low-voltage distribution area line loss rates.

All these metering points for grid supply and sales initially used induction meters, but since 2005 have primarily employed modern electricity meters (electronic meters, smart meters, and future next-generation smart meters).

Development of Domestic Electronic Electricity Meters

Between 2006 and 2016, the authors collaborated with seven organizations—Zhengzhou Wante, Wasion, Chongqing Electric Power Research Institute, Qingdao Neusoft, Dongfang Weisidun, Longji Ningguang, and Chongqing Huali—on application research for high-end electronic electricity meters.

Origins and Development Timeline: - Around 1990, the North China Grid Metering Department first introduced Schlumberger's single-phase electronic (analog multiplier) prepaid meters. - During 1992–1993, domestic design and production began for Class 1 electronic (analog multiplier) single-phase and three-phase meters. - December 2013: GB/T 17215.303-2013 *Digital Electricity Meters* was released. Digital meters have since operated for years in digital high-voltage substations. - August 2016: GB/T 32856-2016 *General Technical Requirements for High-Voltage Electricity Meters* was released. 10kV high-voltage meters have been in operation for over a decade. - May 2017: GB/T 17215.324-2017/IEC 62053-24:2014 *Static Meters for A-C Fundamental Frequency Reactive Energy (Classes 0.5S, 1S, and 1)* was released, marking IEC's first proposal for fundamental reactive energy metering within harmonic metering. - May 2017: GB/T 33708-2017 *Static DC Electricity Meters* was released. In recent years, various DC meter types have entered the market across different industries.

This timeline demonstrates that from 2005–2019, domestic electronic meters evolved from initial development to market dominance, with continuous design and quality improvements establishing a complete domestic electronic meter system with comprehensive accuracy classes and metering categories. However, domestic high-end electronic meters have not yet achieved comprehensive adoption as primary gateway metering devices in domestic grids or penetrated international high-end markets. This gap motivated the collaborative research on high-end electronic meter applications.

Focus Areas of Collaborative Research

The high-end electronic meter application research collaboration focused on: - Analysis and limitations of IEC standards, national standards, and electric power industry standards for high-end meters; - Differentiated designs of imported high-end electronic multifunction meters; - Technical characteristics and quality improvements of domestic high-end electronic meters; - Wasion's electronic meter R&D process; - Discussions on harmonic energy metering, digital meters, and DC meter verification technology; - Design technologies of Landis+Gyr and GE electronic meters; - Special test technologies for identifying three-phase multifunction meter quality; - Promoting domestic high-end electronic meters to become primary gateway metering devices in domestic grids and enter international high-end markets.

Research Outputs and Publications

Based on the collaborative research results and emerging questions, the authors published the following papers: 1. *Development of Three-Phase Multifunction Meter Application Technology and Product Technical Controversies* (March 14, 2005) 2. *Origin and Trends of Multi-Party Collaborative Development in High-Tech Fields of Electronic Electricity Meters* (November 20, 2007) 3. *Multi-function Meter Standards and Performance Evaluation (Quality) Test Methods (Draft)* (June 4, 2008) 4. *Memorandum on Cooperative Research Topics for Electronic Three-Phase Multifunction Meter Quality Test Technology* (October 7, 2008) 5. *Detailed Implementation Rules for Electronic Three-Phase Multifunction Meter Quality Test Methods* (September 16, 2008) 6. *Preliminary Exploration of Grid Gateway Meter Performance Evaluation Test Technology* (February 21, 2008) 7. *Preliminary Exploration of Three-Phase Multifunction Meter Quality Test Methods* (April 1, 2009) 8. *Thoughts and Suggestions on How Chinese Electronic Meters Can Integrate into International High-End Markets* (March 18, 2012) 9. *Why Have Domestic High-End Meters Not Yet Become Primary Gateway Metering Devices?—Research on Performance Differences Between Domestic and Imported High-End Meters and Their Testing Technology* (May 25, 2016) 10. *International Technical Standards for Electronic Electricity Meters in 1997*—Memoirs of 60 Years of Electricity Meter Application Research *(Part 2: Volume 1)* (October 30, 2017) 11. *Wasion: From Entrepreneurship to Pioneering Leadership in China's Electronic Meter Development and Innovation*—Memoirs of 60 Years of Electricity Meter Application Research *(Part 3: Volume 1)* (November 13, 2017) 12. *Application and System Development of Digital Three-Phase Meter Verification Device Technology / Application and Deepening Research of DC Meter Verification Device Technology*—Memoirs of 60 Years of Electricity Meter Application Research *(Part 1: Volume 2)* (November 21, 2017) 13. *Review and Prospects of Harmonic Energy Metering Technology Development*—Memoirs of 60 Years of Electricity Meter Application Research *(Part 2: Volume 2)* (January 26, 2018) 14. *Wasion: Launching China's First 0.1S-Class Settlement Gateway Meter Using Digital Multiplier in 2011*—Memoirs of 60 Years of Electricity Meter Application Research *(Part 3: Volume 2)* (April 5, 2018) 15. *State Grid: The Story of the GE Smart Meter Joint Venture Project*—Memoirs of 60 Years of Electricity Meter Application Research *(Part 4: US GE Meters: Volume 1)* (July 18, 2018) 16. *New Leap in Design Technology for Swiss Landis+Gyr High-Precision Settlement Gateway Meters* (August 15, 2018)

Discussion on Canada's Adoption of Fundamental Active Power Measurement

On July 25, 2019, experts in the China Modern Grid Measurement Technology WeChat Group conducted an extensive and fruitful discussion on online reports that Canada had adopted fundamental active power for electric energy metering.

Overview of Canada's Approach

1. **Implementation Timeline:** Canada mandated that all meters installed in 2021 use fundamental power for energy metering, following cost-benefit analysis by Canadian utilities and review by trade authorities.
2. **International Conference Explanations:** Canada explained at international (measurement) conferences that more consistent models should be used for active and reactive energy metering with sinusoidal signals. Key points from the May 2019 Finland conference discussion included:
   - Traditional "power triangles" for Watts, Vars, and VA based on Budeanu or Fryze power models fail under non-sinusoidal conditions, while the IEEE 1459 power model provides reasonable calculation methods.
   - In many jurisdictions, purchasing or selling energy at harmonic frequencies is illegal, and meters should reflect legal requirements that specify supply frequency as 50Hz or 60Hz.
   - R46 specifies meters using only fundamental energy measurement, and standard devices should be capable of metering fundamental energy.
3. **IEC Contribution:** Canada agreed to provide relevant background information to IEC TC13, emphasizing the importance of using fundamental components for active and reactive power calculation.

Author's Commentary: These reports convey new international trends in energy metering that require domestic study and reference. Key takeaways include: (1) harmonic-frequency energy trading is illegal in many jurisdictions; (2) meters should reflect legal requirements, with R46 mandating fundamental-only metering; and (3) IEEE 1459 provides reasonable calculation methods under non-sinusoidal conditions.

Expert Discussion Questions and Perspectives **1. Direction of Harmonic Active Power** - Red-phase meter measurements indicate harmonic active power is small, with direction fluctuating between positive and negative. - On the user side, harmonic active power is essentially negative. Harmonics generated by loads are negative and quickly attenuate as line losses.

2. Differing Views on Fundamental Metering - Fundamental metering cannot penalize pollution sources. - Per IEEE 1459, distortion power includes Di, Dv, and Dh, with Di having the greatest impact. - Penalizing non-linear pollution loads using current distortion power Di aligns with the "polluter pays" cost principle.

3. Harmonics from Electronic Switching - Current theories inadequately explain harmonics generated by electronic switches. - The energy spectrum distribution differs before and after electronic switches, requiring investigation. - Fundamental energy metering shows significant differences before and after electronic switches, necessitating further study.

4. Rationality of Fundamental Active Power Metering - Support for fundamental metering: China has long tolerated harmonic pollution without adequate control. Only fundamental metering can raise awareness of power quality management among generators and users, potentially driving the harmonic mitigation device industry. - **Legal basis:** Grid transactions involve 50Hz energy, and the revised R46 will likely adopt fundamental-based approaches. Fundamental energy settlement is legally justified under power laws.

5. Applicability of Harmonic Load Power Calculation Algorithms - Non-linear loads have continuous spectra, making DFT algorithms inadequate. Inter-harmonic distortion becomes discretized and unmeasurable, with some standard meters unable to detect it. - Current meters have insufficient bandwidth, resulting in negatively biased energy measurement errors for non-linear loads—effectively under-metering. - The difference between full-wave and fundamental metering is currently small, but would increase significantly if using fundamental + |harmonic| approaches.

6. IEC Standard Developments New IEC electricity meter standards have clearly adopted fundamental reactive measurement for reactive meters.

Author's Perspectives from the Discussion

1. **International Precedent:** Canada's 2021 implementation of fundamental power metering for all new meters sets an international precedent that China's metering industry should study and reference gradually.
2. **Historical Context of Domestic Harmonic Metering Controversy:** The debate dates back to before 1998. In 2004, the China Electric Power Research Institute (CEPRI) Metering Division published a power quality research report highlighting irrationalities in existing grid harmonic metering and calling for methodology changes. CEPRI subsequently submitted reports to national quality supervision authorities, but received no response.
3. **Standardization Gap:** The release of GB/T 17215.324-2017/IEC 62053-24:2014 for fundamental frequency reactive energy metering indicates progress, but active energy metering standards still require revision.
4. **Compromise Solution:** Fundamental active energy metering represents a compromise. It reduces some revenue loss for grids while decreasing harmonic mitigation equipment investment for harmonic source users.
5. **Technical Challenge:** Based on domestic fundamental active meter designs, measurement accuracy degrades after Fourier transformation. Implementing fundamental active metering in China requires new algorithm research.
6. **Strategic Focus:** Fundamental metering is a strategy to rationalize

power trade settlement under harmonic load conditions, not a solution to metering accuracy issues under harmonic currents. The discussion often misaligns these distinct focuses.

Implementation Path for Fundamental Active Metering in China

Implementation requires revising IEC standards, national standards, or electric power industry standards for active power meters to explicitly include fundamental active power metering. After a trial period, domestic acceptance of fundamental active metering will follow. Active coordination between the National Institute of Metrology and CEPRI to adopt fundamental active metering would be highly desirable for the meter industry.

References

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