

# Evolution of Communication Technology in Power Grid Remote Automatic Meter Reading Systems and Electric Energy Metering Management

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**Date:** 2024-01-29T00:00:00+00:00

## Abstract

This paper primarily discusses the State Grid's adoption of remote automatic meter reading system technology for pulse electricity meters in the early 1990s, and how the introduction of electronic meters and smart meters led to rapid updates in local and remote communication technologies, thereby propelling the development of remote automatic meter reading system technology. Between 2010 and 2018, the State Grid undertook large-scale construction of electricity information collection systems for provincial power grids, investing substantial funds in collection equipment and user engineering projects. By the end of 2018, the number of smart meters operated by the State Grid had reached 458 million, with the user coverage rate of the electricity information collection system reaching 99.87%. Regarding communication technologies, the text addresses the developmental trajectories of both local and remote communication methods. Local communication methods evolved from narrowband power line carrier communication technology to broadband power line carrier communication technology, while remote communication methods successively employed GPRS and 4G public network wireless communication technologies. This paper also elaborates on the origin, development, and gradual market phasing out of narrowband power line carrier communication technology, as well as the emergence and development of broadband power line carrier communication technology.

## Full Text

# The Evolution of Communication Technology for Remote Automatic Meter Reading Systems in Power Grids and Electric Energy Metering Management

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## Abstract

This paper examines the evolution of remote automatic meter reading system technology employed by the State Grid Corporation of China (SGCC) since the early 1990s, when pulse-based energy meters were first introduced. The subsequent rollout of electronic and smart meters catalyzed rapid advancements in both local and remote communication technologies, propelling the development of remote automatic meter reading systems. Between 2010 and 2018, SGCC undertook large-scale construction of provincial electricity information collection systems, investing substantial capital in collection equipment and user infrastructure projects. By the end of 2018, SGCC operated 458 million smart meters, achieving a 99.87% user coverage rate for its electricity information collection system.

In communication technology, the paper traces the development trajectory of local and remote communication methods. Local communication evolved from narrowband power line carrier (PLC) technology to broadband PLC, while remote communication successively adopted GPRS and 4G public wireless networks. The paper details the origins, development, and gradual market withdrawal of narrowband PLC technology, as well as the emergence and advancement of broadband PLC technology.

**Keywords:** Remote automatic meter reading system technology; Communication technology

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As early as the early 1990s, several provincial and municipal power grids in China began exploring remote automatic meter reading system technology using pulse-based energy meters. Subsequently, with the introduction of electronic meters and smart meters, local and remote communication technologies underwent rapid updates, accelerating the development of remote automatic meter reading systems. Between 2010 and 2018, SGCC launched large-scale construction of provincial electricity information collection systems, with combined investments totaling 54.7 billion yuan for collection equipment and user engineering projects. The total procurement volume reached 65.12 million collection devices, including 58.5 million concentrators and collectors, and 6.62 million dedicated transformer

terminals. By the end of 2018, SGCC operated 458 million smart meters, with user coverage of its electricity information collection system reaching 99.87%.

## 1. Frequent Communication Technology Updates

**Local Communication Methods** Since the early 1990s, China has conducted pilot programs for remote automatic meter reading of induction-type pulse meters, initially employing RS-485 bus communication and later experimenting with Zigbee low-power wireless communication. After the mid-1990s, domestic power grids leveraged power line resources to pilot narrowband (low-speed) PLC technology, which was deployed at scale following SGCC's electricity information collection system construction in 2010. After 2012, SGCC introduced and domestically developed broadband PLC technology for trial use before expanding its application. During the same period, OFDM narrowband (high-speed) PLC technology was also introduced and domestically developed for batch application, while new low-power wireless technologies such as upgraded Zigbee and WiFi were promoted. Since 2015, SGCC has implemented "multi-meter integration" information collection and data transmission for electricity, water, gas, and heat meters, employing M-BUS bus communication, low-power wireless, dual-mode carrier-wireless communication, and communication protocol converters for water, gas, and heat meter data transmission.

**Remote Communication Methods (Recent Decade)** Remote communication technologies have successively adopted GPRS and 4G public wireless networks, with SGCC currently establishing 4G and 5G private wireless networks for power applications. The Southern Grid has implemented fiber optic communication for remote automatic meter reading in some municipal networks. In mountainous and remote areas without public wireless network coverage, BeiDou satellite positioning and communication are used for meter reading.

**Communication Data Exchange Protocols** After 1997, domestic automatic meter reading systems primarily adopted the DL/T645 "Multi-function Energy Meter Communication Protocol." In recent years, SGCC has introduced DL/T698.45-2017, an object-oriented interoperable data exchange protocol, which remains in the promotion and trial stage.

The following sections describe the evolution of mainstream communication technologies adopted by SGCC.

## 2. The Origin, Development, and Market Withdrawal of Narrowband PLC

In 1994, the metering department of the former Ministry of Electric Power organized testing of imported Israeli narrowband PLC chips and arranged trial deployments in Hangzhou, Beijing, and Harbin power supply departments. A technical exchange conference on automatic meter reading was held in Hangzhou in

March 1998. In 1999, Qingdao Dongsoft launched its first-generation SSC16xx series narrowband PLC chips. The industry standard DL/T698 “Technical Conditions for Low-Voltage Power User Centralized Meter Reading Systems” was released in July 2000. In the same year, Beijing Fuxing Xiaocheng developed the PL2000 narrowband PLC chip. In 2001, China imported the PLT-22 narrowband PLC chip from the American company Echelon, a transceiver dedicated to power line networks. In 2003, the PLC research group at Southeast University published “Power Line Channel Analysis and Modeling” and “Basic Modulation of PLC and Its Improvements,” while scholars from Zhejiang University published “Analysis of Low-Voltage Power Line Carrier Communication Network Structure.” In 2007, Beijing Fuxing Xiaocheng introduced the PL2200 narrowband (BPSK) PLC chip, and in 2008, Qingdao Dongsoft launched its third-generation SSC16xx series narrowband PLC chips.

When SGCC began constructing its power user electricity information collection system in 2009, narrowband (low-speed) PLC technology accounted for 70% of local communication methods due to its low cost. Between October 2009 and March 2014, the authors collaborated with Chongqing Electric Power Research Institute, Wasion, and Qingdao Dongsoft to address prominent issues in narrowband (low-speed) PLC operation, including field testing and evaluation methods for narrowband PLC systems and achieving 100% automatic meter reading success rates within short cycles. Through long-term field and simulation testing, communication testing equipment development, and validation testing, solutions to technical challenges were proposed. In 2014, SGCC’s marketing and metering departments published articles noting that narrowband (low-speed) PLC suffered from slow data transmission rates and low 24-hour automatic meter reading success rates, making it unsuitable for real-time communication requirements of electricity information collection systems. Consequently, narrowband (low-speed) PLC modules were gradually replaced by broadband PLC modules starting in 2016.

It should be noted that OFDM narrowband (high-speed) PLC technology continues to be promoted and applied by SGCC.

### 3. The Origin and Development of Broadband PLC

In 2003, the PLC research group at Southeast University published “W-OFDM Implementation for Broadband PLC,” “Integration of Spread Spectrum Technology in Broadband PLC,” and “PLC Networking Solutions and Applications.” In July 2012, SGCC launched the project “Research and Application of Key Technologies for New-Generation Intelligent Power Line Carrier (150kHz-10MHz) Communication,” which passed acceptance in November 2014. In July 2014, at the technical exchange meeting for the “Imported High-End Meter Full Performance Research” project (Wasion) organized by the authors, Huawei HiSilicon introduced its independently designed Hi3911 broadband (2-12MHz) PLC chip. In November 2014, at the technical exchange meeting on new PLC standards and products (Qingdao Dongsoft) organized by the authors, the focus was on

international and domestic broadband and OFDM narrowband (high-speed) PLC chip technologies. In 2015, Qingdao Dongsoft launched the SSC1663/1664 broadband (1.95MHz-11.96MHz) PLC chips. In October 2016, at the discussion meeting on current industry development hotspots (Chongqing Holley) organized by the authors, Chongqing Electric Power Research Institute introduced field interoperability testing methods for broadband PLC in large public transformer districts (approximately 700 households). In 2017, Chongqing University of Posts and Telecommunications and Chongqing Electric Power Research Institute developed a “Broadband Power Line Impulse Noise Implementation Method Based on System Generator.” In 2017, SGCC released Q/GDW 11612-2016 “Technical Specification for Interoperability of Low-Voltage Power Line Broadband Carrier Communication,” a six-part standard. In May 2018, China Electric Power Research Institute and other domestic units published IEEE 1901.1 “Standard for Medium Frequency (<12MHz) Power Line Carrier Communication Technology for Smart Grid Applications.” During the same period, Qingdao Dongsoft introduced the SSC1667 medium-frequency PLC chip.

#### 4. Recent Wireless Communication Technology Updates and Key Concerns

**SGCC 4G/5G Private Wireless Network Construction** Between 2010 and 2016, most user-side collection terminals in SGCC’s electricity information collection system employed GPRS public wireless networks. After 2016, 4G public wireless communication became the mainstream for remote communication, and SGCC accelerated construction of its 4G private wireless network for power applications. In May-June 2017, pilot projects in Zhejiang and Fujian grids for “Power Wireless Communication Using Carrier Aggregation Technology in the 230MHz Band,” undertaken for the Ministry of Industry and Information Technology (MIIT), passed acceptance organized by the MIIT Radio Administration Bureau. In 2018, China launched 5G public network construction, while SGCC received MIIT approval to plan and construct a 230MHz private wireless network for power applications. The authors’ concern regarding SGCC’s 4G/5G private wireless network construction stems from differing industry perspectives on this initiative.

**NB-IoT Low-Power Wide-Area Networks** The practical application of NB-IoT low-power wide-area networks in smart meter collection systems presents significant challenges. Due to the low collection frequency of NB-IoT technology, it is currently only suitable for remote automatic meter reading of water and gas meters.

#### 2. Problems in Communication Technology Evolution: Shortcomings in Grid Energy Metering Management

**Narrowband (Low-Speed) PLC Methods** Before 2017, narrowband (low-speed) PLC accounted for approximately 70% of local communication methods

in SGCC systems, reflecting a decision to leverage power grid resources. Between 2009 and 2014, the authors collaborated with Chongqing Electric Power Research Institute, Qingdao Dongsoft, and Wasion on narrowband (low-speed) PLC research projects, including: (a) performance evaluation system research for narrowband (low-speed) PLC systems, and (b) pilot projects in Chongqing (Jiangjin) public transformer districts to achieve 100% automatic meter reading success rates within short cycles. However, SGCC's metering departments maintained an incorrect positioning of local communication as low-rate and low-cost, and failed to adequately research and improve narrowband (low-speed) communication channel monitoring and interference suppression technologies. As previously noted, SGCC's marketing and metering departments published articles in 2014 highlighting that narrowband (low-speed) PLC's slow data transmission rates and low 24-hour automatic meter reading success rates rendered it unsuitable for real-time communication requirements of electricity information collection systems. Consequently, this narrowband (low-speed) carrier communication method was gradually phased out.

**Broadband (Medium-Frequency) PLC Methods** Internationally, broadband PLC is primarily used for smart home electrical equipment communication, and its application in automatic meter reading system local communication remains controversial. Domestically, broadband (medium-frequency) PLC technology is being promoted in electricity information collection systems and smart distribution networks. However, SGCC has invested insufficiently in broadband (medium-frequency) PLC channel monitoring, bidirectional interference monitoring, and interference suppression technology research, with few reported studies in these areas. Between 2014 and 2015, the authors collaborated with eight organizations including Chongqing Electric Power Research Institute, Qingdao Dongsoft, and Wasion on broadband (medium-frequency) PLC testing research and technical exchanges.

**Management and Organizational Issues** SGCC's metering departments have merely adopted GPRS and 4G public wireless remote communication methods on a pay-per-use basis, lacking capabilities for independent application improvement and testing. The meter industry administration has focused on promoting narrowband (low-speed and high-speed) PLC technology, equivalently adopting international industry alliance standards; notably, broadband PLC, GPRS, and 4G wireless communication technologies fall outside its scope of responsibility. SGCC's communication departments primarily focus on power fiber optic network operation and maintenance to improve communication quality, and on constructing and promoting 4G and 5G private wireless networks for power applications.

More critically, SGCC's 2009 and 2013 smart meter standards did not address the bidirectional communication and gateway application capabilities inherent in international smart meter standards, nor the advanced interactive functions between distribution networks and users. This represents a significant oversight

in metering management decision-making. It should be noted that after 2015, SGCC's new "multi-meter integration" information collection and data transmission applications adopted dual-mode communication and gateway-based protocol conversion technologies.

These issues emerging from the evolution of communication technology for remote automatic meter reading systems in power grids reflect that SGCC's metering departments have focused on establishing collection equipment standards, pre- and post-bidding testing and acceptance, system operation and maintenance organization, and metering and communication fault handling, while neglecting a crucial aspect: monitoring of low-voltage power line or wireless communication channels and interference, and research and improvement of communication interference suppression technologies. In fact, this communication aspect can only be managed by SGCC's metering departments. It is hoped that SGCC will recognize this importance, take effective measures, increase investment in communication talent and development funds for metering departments, strengthen communication quality control for remote automatic meter reading systems, and fundamentally address this long-standing shortcoming in grid energy metering management.

## References

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*Source: ChinaXiv — Machine translation. Verify with original.*