State Grid Corporation of China and General Electric (GE): Review of Technical Negotiations for the Smart Electricity Meter Joint Venture Project

Authors: Chunhui Zhang, Zhen Zhang, Zhen Zhang

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Abstract

This paper introduces the initial objectives of the GE smart meter joint venture jointly launched by State Grid Corporation, General Electric (GE), Luneng Group, and China Electric Power Research Institute, encompassing the joint venture parties, strategy, objectives, and project progress. Additionally, it describes the GE Smart Power Technology Exchange meeting convened by State Grid Corporation at the China Electric Power Research Institute on July 1, 2009. Attendees included leaders and experts from State Grid Corporation, China Electric Power Research Institute, Luneng Group Company, and GE. During the meeting, GE presented its corporate overview, the technical status of smart meters, and the application of WiMAX wireless communication technology. Participants engaged in in-depth discussions on smart meter technical issues and raised questions requiring further supplementary clarification. The GE smart meter joint venture project was initiated with the objective of establishing one of the world's premier smart meter companies. The technical cooperation between State Grid Corporation and General Electric Corporation (GE) of the United States holds particular significance in the field of measurement. As a historical witness and participant in the technical negotiations, the author finds it necessary to document this historical period.

Full Text

Preamble

Title: Review of Technical Negotiations for the Smart Electricity Meter Joint Venture Project between State Grid Corporation of China and General Electric Corporation (GE)

Authors: Chunhui Zhang[1], Zhen Zhang[2]
[1] State Grid Shandong Electric Power Company, Jinan, Shandong 250001
[2] Huaneng Jinan Huangtai Power Generation Co., Ltd., Jinan, Shandong 250100

Abstract

This paper introduces the initial objectives of the GE smart meter joint venture project jointly launched by the State Grid Corporation of China, GE, Luneng Group, and the China Electric Power Research Institute, including details on the joint venture parties, strategic framework, goals, and project progress. It also documents the GE Smart Power Technology Exchange Meeting held at the China Electric Power Research Institute on July 1, 2009, which was attended by leaders and experts from the State Grid Corporation, China Electric Power Research Institute, Luneng Group, and GE. During this meeting, GE presented its corporate overview, technical status of smart meters, and application of WiMax wireless communication technology. Participants engaged in in-depth discussions on smart meter technical issues and raised questions requiring further supplementary explanation. The GE Smart Meter joint venture project aimed to establish one of the world's leading smart meter companies. The technical cooperation between the State Grid Corporation of China and General Electric holds special significance in the field of electric power measurement. As a historical witness and participant in these technical negotiations, the author finds it necessary to document this important period.

Keywords: State Grid Corporation, General Electric Corporation, smart meter

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Foreword

On May 21, 2009, the State Grid Corporation of China released its "Strong Smart Grid Development Plan (2009-2020)." Prior to this release, the State Grid had organized visits to European and American countries to investigate smart meter construction and advanced metering infrastructure (AMI). In June 2009, the State Grid Corporation of China, Luneng Group Corporation, China Electric Power Research Institute, and GE Corporation of the United States jointly launched the GE smart meter joint venture project. The author of this article served as the technical consultant for the Luneng side of the joint venture project.

Initial Targets of the GE Smart Meter Joint Venture Project

On June 17, 2009, Luneng Holding Group Corporation convened a meeting for the GE Smart Meter Joint Venture project and introduced the preliminary plan:

1. **Joint Venture Parties:** Luneng Group Corporation, China Electric Power Research Institute, and GE Company

2. **Strategy:** Luneng Holdings would operate as a privatized entity with access to the State Grid market

3. **Objective:** To build the venture into one of the world's top smart electricity meter enterprises

4. **Project Timeline:**
   - Technical communication with GE technicians by end of June 2009
   - State Grid issuance of requirements for smart meter standards, functions, and technologies on July 20
   - Completion of GE smart meter testing by end of July
   - Comprehensive evaluation and screening of domestic meter enterprises with cooperation negotiations before August 31
   - GE conversion of US standards to IEC electronic electricity meter standards by September 30
   - Joint completion of the GE Smart Meter joint venture feasibility report by September 30

Summary of the GE Smart Meter Technology Exchange Meeting

On July 1, 2009, the State Grid Corporation held a GE Smart Power Technology Exchange Meeting at the China Electric Power Research Institute.

Meeting Participants

- **State Grid Corporation:** Head of the Metering Department
- **China Electric Power Research Institute:** 9 leaders and experts

- **Luneng Group Corporation:** 6 company leaders and experts, including Wang Yunquan from the Shandong Institute of Electricity (the author of this article)

- **GE Company:** 6 company leaders and experts

Meeting Summary

GE Company Presentation: GE Energy Group is headquartered in Alexandria, with business operations spanning water, electricity, gas, and other sectors, backed by many years of experience in electricity meter operations. GE's electricity meter products primarily follow ANSI standards, with the third generation of ANSI-standard smart meters introduced in 2009. Currently, GE smart meter communication relies mainly on WiMax wireless technology. Beyond conventional meter functions such as energy measurement, remote control, and time-of-use (TOU) pricing, GE's smart meter technology is distinguished by its Internet router capabilities and ability to read water and gas meters. GE showcased two ANSI-standard smart meters—the I-210C+ and KV2c—briefly introducing their characteristics. Both meters are designed based on ANSI standards, with differences from IEC standards primarily reflected in mechanical structure, accuracy requirements, rated current, data structure, and clock accuracy. GE experts emphasized that their smart meter technology meets WiMax wireless broadband communication requirements for high-speed two-way communication. WiMax network systems are primarily constructed and operated by local telecommunications departments, with GE smart meters incorporating third-party WiMax modules operating according to rules set by the supply company. While WiMax power wireless communication was not permitted in China at the time, the application of GPRS, 3G, and other technologies could be explored.

Technical Discussions: The China Electric Power Research Institute and Luneng Group Corporation communicated with GE on smart meter technical issues, focusing on several key areas:

- **GE Smart Meter Failure Rate:** The failure rate of GE smart meters within 1-2 years is 0.1-0.2%. GE considers this normal, as meters in the United States are only sampled for testing.

- **Current Application Scale and Cost:** GE smart meters have been trialed in Australia and the United States, with 4,000 units currently deployed. The cost per GE smart meter is approximately $200 / meter, and GE designs and produces around 1 million PLC and RF based meters for around $150.

- **Prepaid Standards and Data Security:** Since prepaid systems are rarely used in the North American market, GE smart meters have no reference standard for prepaid functionality. Data and information

security primarily depends on communication channel security; for example, switch control relies solely on password protection. Currently, GE's prepaid mode mainly depends on real-time two-way communication systems for remote prepaid implementation.

- **Advantages and Disadvantages Compared to Other Enterprise Meters:** Discussion of comparative merits.

- **Multi-function ANSI Standards:** No specific multi-function meter standard currently exists; multi-function meter design only references other standards.

- **ANSI vs. IEC Standard Advantages:** GE believes ANSI standards feature a plug-in structure for easier installation, with ANSI electricity meters achieving higher accuracy, most reaching 0.2 class.

- **Benefit Analysis for North American Market:** GE's North American plant produced approximately 2-3 million units in 2008 and about 500,000 units in the Philippines, though no specific benefit analysis report was available.

- **Smart Features:** High-speed two-way communication enabling Internet router functionality; built-in switch control up to 320A; capability to read water and gas meters.

Outstanding Issues Requiring GE's Supplementary Explanation:

- GE should provide testing sample meters, testing systems, and testing methods as soon as possible.

- Design description of the I-210+C single-phase smart meter (translation of specifications).

- Meter performance meets or exceeds ANSI standards: C12.1, C12.10, C12.18, C12.19, C12.20, and C37.90.1 (Note: The ANSI C12 series covers communication protocols for electrical metering equipment. C12.1—Electrical metering specifications; C12.10—Electromechanical electricity meter protocol specification; C12.18—ANSI Type 2 optical interface; C12.19—Utility industry terminal equipment data sheet; C12.20—0.2 and 0.5 accuracy class electricity meters; C37.90.1—Protective appliance testing and operation).

- Advantages and disadvantages of ANSI standards compared to IEC standards.

- Accuracy of GE smart meters at 0.01 power factor.

- List of proprietary technologies and patent application schedules used in all GE electricity meters (excluding mechanical meters).
- Power consumption of GE smart meters in each communication mode.
- Harmonic collection method of GE smart electricity meters.
- GE's proposed cooperation steps for upcoming collaboration.

I-210+C Technical Specifications:

- **Electrical Systems:** Voltage: 120/240V $±$20%; Temperature: -40°C to +85°C; Typical starting wattage: $ $5W; Typical watt loss: 0.7W; Typical accuracy: within $±$0.2%; Design life: 15 years.
- **Record Selection:** kWh records (normalized per meter) for delivered only, received only, delivered + received, delivered - received; kVarh reactive power records; kVAh (vector view) records; minimum, maximum, average voltage records calculated by RMS algorithm; Sag/Swell records.
- **Time-of-Use Application Records:** Requires T2 software switch; 4 rates applicable to each total and demand value; 2 collections such as outgoing/receiving kWh recorded per rate (A, B, C, D); 4 seasons with 3 typical days and 1 holiday per season; 80 switch operations; 50 programming dates (supporting non-recurring, fixed recurring, and floating recurring dates); 2 backup power options (battery with 1-year carrying period or rechargeable ultracapacitors with 8-hour carrying period).
- **Load Curve/Interval Records:** Requires R2 software switch; stores 1-4 channels of data; with strong memory selection, can store 4-channel data at 5-minute intervals for up to 35 days.
- **Demand Calculation:** Requires N2 software switch; selects any two quantities from square demand, rolling demand, heat demand, maximum demand, accumulation demand, and continuous accumulation demand.
- **Event Logging:** Requires E2 software switch; records up to 200 events with date/time stamps when T2 switch is installed; applicable events include warnings, power off/on, meter programming, demand reset, self-reading, test mode input/output, real-time price activation/invalidation.
- **Warnings:** Low-voltage battery warning, non-programming warning, program missing warning, DC detection warning, low potential warning, overload demand warning, reactive power advance warning, active reverse warning, running error detection.

- **Remote Circuit Breaker:** (Omitted)

- **Key Components:** Measurement chip (32-bit CE, 8-bit MPU, 16 kB ROM, 2 kB RAM); Microcontroller (256 kB Flash ROM, 12 kB RAM); EEPROM (256 kbit for data and program parameters); Crystal oscillator (32 kHz for timing).

Differences Between ANSI (C12) and IEC Electricity Meter Standards

A summary of this section was reported online on April 15, 2010: "ANSI and IEC Electrical Metering Standards Are Not the Same."

1. **Physical Design:** The most obvious difference is that ANSI meters are circular and plug into sockets, while IEC meters are rectangular with junction boxes designed to accept striped wires. These patterns developed in the early 20th century, with IEC instruments mainly used indoors (or under protective covers) and ANSI instruments primarily for outdoor use. Because ANSI instruments are used outdoors, they have wider operating temperature ranges and provide better climate protection. However, it should be noted that the IEC standard also has a complete set of expanded temperature ranges for outdoor instruments, and the standard determines the socket instrument style.

2. **Standard Similarities:** There are many similarities between the two standards. Since IEC and ANSI instruments share the same primary functions, both specify many identical tests, including accuracy requirements for starting current, latent current, load current, voltage, and power factor, as well as immunity to external influences such as voltage surge, current surge, magnetic field, electrostatic discharge, and radio interference. However, differences exist in test grades and conditions.

3. **Testing Conditions:** IEC and ANSI instruments are not tested under exactly the same conditions, though both apply to 50Hz and 60Hz frequencies. The ANSI standard fully defines external wiring size and shape for socket instruments (S base) and junction box instruments (A base), while the IEC standard omits junction box size specifications.

4. **Key Measurement Differences:**

    - **Current Rating Method:** ANSI standards determine a few maximum current values (e.g., 200A or 10A), with performance requirements for all other loads based on this classification. ANSI calibration points use midscale calibration as the basis for other performance requirements. For directly connected IEC meters, the term "basic current (Ib)" is used, while "rated current (In)" applies to transformer-connected instruments. In IEC instruments,

maximum current differs from basic or rated current.

- **Terminology:** In ANSI standards, the term "grade" refers to the maximum current rating (e.g., a grade 20 instrument has 20A maximum current). In IEC standards, "grade" refers to accuracy specification (e.g., a class 2 instrument has 2% basic accuracy).

5. **Communication Standards:** Partial compatibility exists between ANSI and IEC communication standards. Recently released IEC protocol standards enable use of ANSI C12.19 charts. For safety reasons, both ANSI and IEC instruments use optical channels through the housing with identical physical spacing and optical signals, though transmitters and receivers are opposite. Despite these differences, optical plugs and adapters can be manufactured for any instrument type.

Evolution of the State Grid-GE Smart Meter Joint Venture Project

The following describes the project progression after July 1, 2009:

On August 10, 2009, the author and senior experts from Luneng Group traveled to the Beijing State Grid Communication Company to discuss smart meter communication requirements, though experts from the China Electric Power Research Institute were absent. On August 18, 2009, the State Grid Corporation of China released the first 2009 version of the State Grid smart meter series enterprise standard.

It was anticipated that in the fourth quarter of 2009, Luneng Group Corporation, China Electric Power Research Institute, and GE would form Shandong Electronics Company as a joint venture to produce Luneng brand smart electricity meters, with Luneng Group as the majority holder, China Electric Research Institute responsible for technology, and GE as the investor. At this point, the author ceased serving as the general consultant for the Luneng side.

On June 2, 2010, Shandong Electronics Company held a discussion in Beijing on the Luneng smart meter design outline, which the author attended. During the meeting, experts from China Electric Power Research Institute introduced the 2009 version of the State Grid smart meter series enterprise standard, which would be converted into the Luneng smart meter design outline. On July 20, 2010, the company held a meeting in Jinan on Luneng smart electricity meter process design and key equipment selection, also attended by the author.

On October 20, 2010, Shandong Electronics Company convened a discussion in Jinan on the Luneng smart electricity meter technology scheme. The author attended this meeting, where a Nanjing company introduced a single-phase smart meter design scheme and a Changsha company presented a three-phase

smart meter design scheme, though no definitive Luneng smart electricity meter technology scheme was established.

On February 20, 2011, Shandong Electronics Company held the Luneng smart electricity meter production process equipment review meeting in Jinan. Attendees included 12 evaluation experts from Shandong Metrology Institute, Zhengzhou Sida Company, and Weisheng, Linyang, plus the author, along with 12 leaders and experts from Shandong Electronics Company. A design institute from Hangzhou delivered a special report on the process scheme evaluation for the Shandong Electronics Company electricity meter construction project.

On March 8, 2011, Shandong Electronics Company conducted the first-phase bidding meeting for the single-phase smart meter production line in Jinan, with the author participating in bid evaluation. Five bidders participated: Henan Star, Zhengzhou San'an, Haiyan Hanpu, Nanjing Automation Factory No. 3, and Haiyan Company. On April 26, 2011, the second-phase bidding meeting for single-phase intelligent electric power production line equipment was held in Jinan, again with the author as a bid evaluator. Seven tenderers participated: Nanjing Automation Factory No. 3, Shanghai Sichuan, Haiyan Shengdi, Zhengzhou Sihui, China, Henan Star, Hangzhou Houda, and Haiyan Xinyue.

On March 9, 2012, the author met with GE experts from Shandong Electronics Company in Jinan to discuss the performance evaluation method for GE's KV2c three-phase electricity meters. The GE specialist indicated that Shandong Electronics Company planned to introduce a 0.5S class three-phase electricity meter scheme from a domestic company, embed characteristics of GE's KV2c three-phase meter, and develop it into a 0.2S class three-phase meter to enter the State Grid centralized bidding for 0.2S class meters. However, developing smart meters according to State Grid smart meter series standards would involve a long cycle and high costs. The author noted that Weisheng's 0.1S class three-phase meter had been developed according to main meter metering requirements, suggesting that Shandong Electronics Company's high-end three-phase meter development plan required careful reconsideration. The author offered that performance testing and evaluation of GE's KV2c three-phase electricity meter in China could be entrusted to the Chongqing Institute of Electricity Science, which has extensive experience in meter testing, with the author available to provide assistance if needed. The GE specialist indicated that the company's stake in Shandong Electronics might be withdrawn, with all leaders and experts returning to Beijing.

By 2013, according to the State Grid's unified institutional adjustment plan, Shandong Electronics Corporation was fully taken over by the State Grid Xuji Group Corporation, marking the official end of the State Grid-GE smart meter joint venture project.

Summary

Technology Exchange Conference on July 1, 2009: State Grid-GE Smart Meter Project Speech

In 1996, Shandong Power Grid imported American GE Company 0.2 class KV three-phase electronic electricity meters in batches, which were still operating and measuring on the power grid in 2009. In March 1997, the author studied and trained at GE's electricity meter factory as part of a Shandong Electric Power Company delegation. Thus, Shandong Power Grid had early familiarity with GE KV-type electricity meters. The KV2c meter presented at this meeting represents a new development based on the original KV meter.

After 20 years of development, China's electronic electricity meter industry has established a complete product system ranging from class 2 to 0.2S. However, compared with international brands like GE, domestic electricity meters still show many differences, necessitating advanced technology introduction and expanded development. The author hoped to discuss several design and application issues with GE experts: whether measurement error is calibrated at 0.01 power factor; harmonic reactive power metering algorithms; whether the United States has established a reactive power measurement value transmission system (which China has not yet built); GE's development topics for IEEE1459 standard applications; and why KV2c meters use WiMax wireless rather than broadband carrier communication, given that IEEE and the Home Plug alliance have issued many carrier communication standards.

GE experts responded that GE meter design experts would need to address these questions subsequently.

Joint Venture Project Turning Point:

In 2009, the State Grid-GE smart meter joint venture project shifted direction. Compared with the 2009 version of the State Grid smart meter, GE smart meters offered many features: wide voltage working range for convenient application; maximum current range up to 320/200A; plug-in structure with high processing accuracy and access without power failure; circular shell design for outdoor high-temperature resistance; high accuracy with single-phase meters at 0.2/0.5 class; sinusoidal electric energy measurement functions and multiple voltage measurement functions; large load curve storage capacity; metering chip configuration with 32-bit CE and 8-bit MPU; rechargeable ultracapacitors for power outage backup; and high-speed two-way communication enabling Internet router functionality.

However, compared with the 2009 version of State Grid smart meters, GE smart meters had shortcomings: no reference standard for prepaid functionality; fewer professional application functions; and higher pricing levels. Therefore, by comprehensive performance measures in 2009, GE smart meters were not suitable for the multi-functional, low-cost requirements of the State Grid electricity information collection system.

It should be noted that the 2013 version of the State Grid standard smart meter had limitations: single-phase meters only measured active power without reactive power or visible grid metering; three-phase meters lacked visible metering. This measurement method was incomplete and did not meet future high-quality intelligent distribution network construction needs. Through the State Grid-GE smart electricity meter joint venture project, understanding of ANSI standards was deepened, which would benefit domestic electricity meter design improvement and export efforts.

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About the Authors:

Chunhui Zhang (1938—) is engaged in research on energy metering technology.
Corresponding author: Zhen Zhang (1977—) is engaged in research on electric energy metering technology.
Email: 721047546@qq.com

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