Research on the Construction of Intelligent Meter Reading System Based on Energy Metering Integrated Acquisition Technology

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Abstract. At present, the energy metering equipment used by Chinese residents mainly covers electricity meters, water meters, gas meters and heat meters, which are separately managed by different enterprises in the four energy industries. However, in addition to the power industry, the other three energy industries have not yet established enterprises that operate on a national basis, which poses a major challenge for the management of operations and management. The meter reading fee is difficult to become a major problem. To this end, the integrated measurement of electricity, water, gas and thermal energy has become an exploration of the State Grid focusing on resource intensive construction. Based on the research background, this paper establishes an energy metering integrated intelligent meter reading system. Based on the requirements of the system, the paper designs the functional structure, technical architecture system and operation management mode of the intelligent meter reading system. It is expected to realize electricity, water, and the gas and thermal energy measurement management system group standard design is based on the “Internet +” electricity, water, gas, and thermal energy measurement business operation mode, and establishes an integrated operation system for meter reading, charging, operation and maintenance, and service.

1. Introduction

Electricity, water, gas and heat are essential public service energy products for people's daily lives. Whether they can achieve accurate and reliable measurement is closely related to the vital interests of everyone. At present, energy suppliers and energy marketers in most countries in the world are independent of each other. Energy suppliers are only responsible for the transportation and supply of electricity, water, gas, heat, etc. Energy marketers are only responsible for energy measurement and data collection. For energy marketers, the establishment of an integrated collection system for electricity, water, gas and thermal energy metering can significantly reduce construction and maintenance costs. However, because the integrated measurement of energy metering requires a higher technical level of communication infrastructure, countries do not agree on their views: the UK government actively promotes the construction of smart meter and smart gas meter two-in-one system,
the total investment amount. It has a total investment of 11 billion pounds and plans to achieve full coverage by 2020. The Netherlands has clearly proposed the use of electricity meters as a gateway to collect water and gas meter data. It plans to invest 26 billion yuan in 2012-2020 for the installation of 15 million smart phones. Electricity meter and smart gas meter; Denmark consists of eight public utilities that provide electricity, heat, and water services. The alliance has invested in a comprehensive platform for smart electricity, heat and water. The platform was built by Cambrou. There are 153,000 electric, hot and water meters in total; South Africa netVendor cooperates with China's Wasion Company to build electricity and water collection projects. The pilot scale of the project includes 660 STS wireless water meters and more than 700 Wasion ameter100 electric energy meters. The success rate of the table is 100%, and the success rate of single meter reading is 99.7%. China's energy metering integration work started late. At present, in addition to the power industry, other energy industries have not yet completed an intensive and large-scale measurement information collection system. Due to different operating departments, residents need to pay electricity, water and gas fees separately. Hot costs, cumbersome procedures, time-consuming and laborious [1].

In 2015, the State Grid Marketing Department organized experts from various fields to carry out multi-integration and collection construction work, and based on the existing power consumption information collection system architecture system, successively carried out a series of typical technical program application pilots. However, due to some unavoidable technical problems in the current acquisition system, large-scale copying and application of water, gas and heat meters requires a large number of intelligent functional transformations.

2. Research on Technical Architecture System of Integrated Measurement System for Electricity, Water, Gas and Thermal Energy Measurement

2.1. Energy metering integrated acquisition system functional architecture

According to the requirements of future business development, the functions of the energy metering integrated collection system side include basic applications, advanced applications, operation management, statistical analysis, and system support. The terminal side includes the terminal function application part. The functional architecture of the system is shown below:

![Figure 1. Energy metering integrated acquisition system functional architecture.](image-url)
The basic application refers to general collection business applications, including file management, terminal management, data collection management, interface management, etc.; advanced applications refer to advanced measurement and cross-professional business applications, including online monitoring of metering devices, intelligent fee control, and line loss analysis. Four-in-one application, etc.; operation management includes acquisition channel management, clock management, intelligent operation and maintenance, etc.; statistical analysis includes system construction, energy analysis, load analysis, report analysis, etc.; system support provides bottom-level support for system operation, includes rights password management, code management, and template management. Terminal function applications include data acquisition, data processing, parameter setting, terminal control, event recording, data transmission, terminal maintenance, terminal upgrade, and edge services.

2.2. Energy metering integrated acquisition system logic architecture

The project draws on the experience of the most advanced power information collection system in the energy industry, and carries out the architecture design of the metering integrated acquisition system. The system logic architecture is shown in the following figure, which consists of four parts: cloud, tube, edge and end.

![Energy metering integrated acquisition system logic architecture](image-url)

Figure 2. Energy metering integrated acquisition system logic architecture.
2.2.1. Device side. The equipment end refers to all kinds of equipments connected to the energy metering integrated collection system, including the collection terminal equipment and metering equipment; among them: the metering equipment is mainly used for electric utilities, water meters, gas meters and heat meters. Based on the standard communication protocol, the device type accessed by the device can support elastic expansion.

2.2.2. Edge calculation layer. It mainly includes the following parts: function flow calculation, device protocol and model conversion, device data analysis and arrangement, data coordination, resource coordination, and intelligent coordination. Function flow calculation implements an edge calculation framework that supports function calculation, rule engine and flow calculation, and provides intelligent services for image recognition, machine learning model prediction, and speech recognition. Device protocol and model conversion, support data exchange mode of wired and wireless communication modes of multiple meters, conversion of multiple protocols, and establish a universal data interaction model of multi-source heterogeneous, plug-and-play metering equipment. Device data analysis and programming, mainly including data acquisition input, data processing, database and memory storage and application. When the application needs to call the protocol library to perform data processing and protocol analysis on the electricity, water, gas, and heat meters, the data is entered, analyzed, and packaged and sent in sequence. Data collaboration enables data synchronization with the cloud and local caching in an offline state. The resources cooperate to realize the coordinated processing of resource allocation and tasks of cloud resources and edge computing. Intelligent collaboration, training machine learning model in the cloud, and sending the model to the edge side, the edge side based on the model for pattern matching and recognition.

2.2.3. Pipeline layer. The narrowly defined pipeline layer refers to the network channel from the device layer to the system front communication layer, which is commonly referred to as the acquisition uplink communication channel. The generalized network layer also includes a network channel for collecting communication between the terminal device and the metering device, that is, a so-called acquisition downlink communication channel. The acquisition of the uplink communication channel usually includes the following communication methods: wireless public network (GPRS/CDMA, etc.), optical fiber, 230M wireless private network, 4G, etc.; with the rapid development of network technology, 5G, LTE230, 10G-EPON, etc. will be included in the future. High-speed communication method. The downlink communication channel usually includes the following communication methods: RS485, narrowband carrier, micropower wireless, M-BUS, etc. In order to meet the future high-frequency data acquisition requirements, it is expected to introduce high-speed narrowband carrier, dual-mode or multi-mode communication in the future. New technologies such as near field communication.

2.2.4. Cloud layer. (1) IoT management platform. Including data quality control, task pool intelligent scheduling, Web service clustering, collection and operation closed loop, background service cluster, collection performance monitoring, big data platform monitoring, cache service, security authentication service, etc. The data quality control module is mainly responsible for screening and checking the abnormality and missing of the collected data to ensure the validity and rationality of the system data application and data release. The intelligent scheduling of the task pool is a task that the front station generates and needs to be sent by the front-end machine. The front-end machine rotates the load and caches the task, and the control task is automatically delivered to implement different queues of different terminals, and supports different queues to send and increase the delivery speed in parallel. The task is delivered and the frame number of the returned frame is checked to ensure the correctness of the data. The automatic retransmission mechanism of the task fails to be sent to increase the success rate of the delivery process, so that the log processing of the task is convenient to check the problem, thereby avoiding waiting for the foreground operation of the main station. The user experience, the front-end machine task supports millions of data delivery, and the delivery success rate
is more than 95%. The Web service cluster is responsible for providing various types of collection service application functions to the system users, and interacting with the communication layer through the message queue. The acquisition operation and maintenance closed loop is responsible for completing the closed loop processing of various operation and maintenance work orders of the system. The background service cluster is a background service application that monitors and schedules various applications of the system [2]. The collection performance monitoring application monitors the running status of each functional node of the primary station system by collecting various program node output logs or integrating monitoring visualization tools provided by other third parties. Big data platform monitoring is to monitor the running status of each node related to cloud storage and cloud computing. The cache cluster is mainly responsible for the following tasks: buffering data collection in batches, reducing the pressure of storage; saving various common parameters used by the front module to improve application efficiency. The security authentication service performs protocol adaptation processing through HTTP/private protocol, etc., and completes data access and standardization of the system or terminal. Externally deployed on the Internet side of the IoT management platform, and the edge of the agent can use the common authentication and encryption measures of the external mature Internet of Things platform. For the IoT management platform deployed on the information intranet side, it is necessary to follow the company's existing security protection framework uses a high-strength security authentication encryption method such as the National Secret VPN for customized development.

(2) Data storage platform. Storage consists of a production database (that is, a traditional relational database) and a distributed data warehouse. Among them: the production database includes the main application database and the historical database. The main application database stores the archive data of the acquisition system, the business data of the past one year, and the like; the historical database stores the historical business data migrated from the main application database. Distributed data warehouse storage content includes distributed file storage, distributed message databases, and distributed in-memory databases. Among them: distributed file storage is responsible for storing and collecting basic files, collecting original data, calculating intermediate data, etc., providing support for real-time, timing data calculation and communication analysis; distributed message database is responsible for storing all terminal reports generated when communicating with the collection terminal. The distributed in-memory database is responsible for storing the archive data and the result data of the real-time calculation.

(3) Big data processing platform. Including real-time processing, distributed stream computing, distributed offline computing, file synchronization, log collection, and more. Real-time processing, for the execution of tasks corresponding to various data items collected by water, electricity, gas and heat meter, real-time flow processing technology is used for real-time auditing of tasks, accurate and rapid positioning of tasks that fail to perform, and easy to be used as a failure record The basis for re-initiation is to improve the success rate of data collection success rate of multiple energy sources. Distributed stream computing includes real-time data calculation and real-time communication analysis. The real-time data calculation is responsible for receiving the data in the message queue and completing the instant calculation processing (such as terminal communication traffic analysis), and saving the result to the distributed in-memory database; the real-time communication analysis is responsible for monitoring the uplink part characteristic data to trigger the real-time calculation processing, through one The series of communication interactions completes business analysis (such as effective power outage analysis) and saves the results to a distributed in-memory database; distributed offline calculations include timing data calculations and timing communication analysis. The timing data calculation completes the data calculation task (such as power calculation and load analysis) according to the specified time period, and saves the calculation result to the main application database; the timing communication analysis triggers the data analysis task according to the specified time, and completes the communication interaction operation (such as data leakage point Recall), and save the calculation results to the main application database; the file synchronization module is responsible for real-time acquisition of incremental changes in the production database file
data, and batch synchronization to distributed file storage; the log collection module is responsible for collecting the output of various computing nodes. The log is provided to the operation and maintenance monitoring application as a system monitoring data support.

(4) Micro application platform. The micro-application platform includes micro-applications such as energy analysis, fee control management, terminal services, report management, loss management, decision analysis, smart home, load analysis, and intelligent operation and maintenance. Based on Eclipse, Gradle, and Spring Cloud, the micro-application based on the micro-service development framework encapsulates, develops, and integrates various plug-ins and components. The microservices projects in the SG-UAP microservice development framework are divided into microservices main projects and microservices projects. The main station microservices main project stores all common components and configurations. The module functions microservices projects store private components, configurations and actual business logic. Realization, support the main station microservice overall architecture business application to quickly build [3].

2.3. Energy metering integrated acquisition system technical architecture

2.3.1. Overall technical architecture. The energy metering integrated collection system faces the users of electric, water, gas, and heat service enterprises. Considering the application needs of users in the future, such as energy analysis, user interaction and demand side management, the data collection range, data frequency, and acquisition frequency all require higher requirements. Therefore, the system main station architecture design uses massive acquisition object access, massive data processing, storage and other data processing technologies, and the communication architecture is designed with wireless devices. Wake-up mechanism, high-speed and high-reliability interface data transmission, heterogeneous network architecture and other technologies. The device architecture design adopts a universal data interaction model that supports plug-and-play metering equipment, and supports protocol library technology for multiple meter communication protocols. Automatic synchronization of source heterogeneous terminal files, collection of terminal fault intelligent diagnosis and other technologies. The overall structure of the energy metering integrated collection system is as follows:

![Figure 3. The overall technical framework of the energy metering integrated acquisition system.](image-url)

2.3.2. Master station technical architecture. The communication processing layer supporting massive communication access should include 5 major parts: communication gateway cluster, communication pre-cluster, communication scheduling cluster, message queue cluster and data inbound cluster. The
communication gateway cluster realizes the communication link function of the communication layer; the communication scheduling cluster realizes the communication scheduling function of the communication layer; the service processing function of the communication layer is realized by the three independent functional modules of the communication front-end machine, the message queue, and the data storage. The architecture is as follows.

**Figure 4.** Technical architecture design supporting massive communication access.

Communication gateway cluster: implements the link maintenance function of various channels of the terminal, distributes the abnormality or the amount of distribution exceeds the processing capacity, and the file cache function of the text, gprs/cdma and the fiber terminal access the communication gateway through the load balancer to realize the cluster; SMS, 230M and the Beidou satellite communication terminal realizes the cluster by the dual-machine mutual backup due to the channel characteristics.

Communication pre-cluster: implements most of the service functions of the communication layer, including file loading and synchronization of specified terminals, downlink request message queue acquisition, encryption machine interface call, downlink message framing, multi-terminal parallel single terminal serial delivery strategy Implementation, uplink and downlink packet management, uplink and downlink packet transmission and reception, terminal service status maintenance, uplink packet parsing, and message queue push [4].

Communication scheduling cluster: Implements policy distribution and dynamic adjustment of packet forwarding between the communication gateway and the communication front-end. Policy distribution can be implemented by algorithm partitioning of the terminal address domain. Dynamic adjustment can adjust the distribution policy by monitoring the running status of all nodes of the communication gateway and the communication front-end. The purpose of policy forwarding is to reduce the memory overhead (file loading, terminal working conditions, etc.) of the communication front-end machine by adding nodes. The low memory overhead can improve the stability and robustness of the program. After the policy is allocated, the terminal is relatively fixed. A node framing is defamed to prevent the terminal from generating additional data synchronization because of the cross-node uplink and downlink correspondence. The purpose of dynamic adjustment is to realize the communication front-end cluster function by dynamically adjusting the distribution policy through node monitoring information in order to encounter node failure.

Message Queuing Cluster: Implemented by Kafka cluster technology, which reflects the function of data bus in the logical architecture. The communication layer, application layer and storage layer
can exchange data through message queue. The message queue stores the downlink request queue, the uplink response queue, the parsing data queue, and the streaming data queue. When multiple external program modules obtain the same queue data, the queue uses the subscription mode to meet the demand. The downlink request is uniformly buffered and maintained through the message queue. The advantage is that the application layer does not need to pay attention to the distribution of the terminal in the communication front-end cluster. The nodes of the communication front-end cluster do not need to maintain the excessive downlink request queue. The downlink request of each terminal managed by the message queue and the downlink request that can be processed in a timely manner are obtained, and the policy queue can also be cleaned when the downlink request of the message queue is excessive. The uplink response queue stores response data that requires real-time response, such as the recruitment, setting, and control of the application layer request. The data queue is parsed to store task data and abnormal events after the uplink packet is parsed [5]. The stream data queue stores the uplink and downlink packets and the cloud platform needs to calculate the required parsed data in real time or timing.

Data warehousing cluster: The parsing data (upper task data and abnormal events) pushed by the communication front-end machine in the message queue is stored in the production database according to the efficient saving policy. The analysis data storage function is independent from the communication front-end cluster. It is mainly considered that the number of connections to the production database will be limited after the node is expanded to a certain number. The discrete distribution of the terminal communication front-end machine will also affect the efficiency of production data storage., so independent storage can improve storage efficiency and reduce database overhead.

In order to meet the application requirements of efficient storage of massive data, it is necessary to include two parts: production database and cloud platform. The production database includes a main application database cluster, a historical database, and a disaster recovery database; the cloud platform mainly includes a distributed file storage, a distributed message database, and a distributed in-memory database. The technical architecture diagram of the storage layer is shown in the figure below.

![Figure 5. Technical architecture design supporting massive data storage.](image)
The main application database, disaster recovery database, and historical database in the electricity information collection system are recommended to be stored in a mature stable relational database (such as Oracle). The main application database retains the service data in the past one year, and the previous historical data is periodically migrated to the historical database, and the disaster recovery database performs data replication from the main application database in real time.

3. Operation mode analysis

3.1. Ways of cooperation

The typical cooperation methods of energy metering integration can be divided into five types: copying, collecting, urging, dynasty, and free sharing. The copying business is the responsibility of the grid enterprise for the unified meter reading of the customers who realize the integrated measurement of energy metering, and provides the meter reading data. The entrusting unit is responsible for checking the meter reading data and paying the grid company for copying the service fee. The collection business refers to the type of business that the entrusting unit entrusts the power grid enterprise to collect water, gas and heat charges (which can provide integrated SMS reminder service) and pay the collection fee. Uniform electricity, water, gas, hot meter reading cycle and bill generation date, generate energy measurement "one household and one bill", and promote "one household receipt". The agent business refers to the type of business that the entrusting unit entrusts the power grid enterprise to charge water, gas and heat, and pays the handling fee. Based on the energy measurement data obtained by the copy service, the bill information is automatically pushed to the user through the mobile phone short message, WeChat public number, handheld power APP, etc., and the user is guided to pay online. Devi business refers to the entrusting unit entrusting the grid enterprise to conduct a general survey of water, gas and thermal energy metering, and to report the accurate fault meter information to the entrusting unit, and to replace the business type of the fee. The grid enterprise area manager regularly conducts a general survey on the operation status of the meter and the accuracy of the meter reading. After the professional training, the grid enterprise area manager will check the on-site water, gas and heat energy meter at one time, which will effectively shorten the census time and save the scene. The number of workers will improve the efficiency of operation and maintenance. The free sharing business is a power grid enterprise. The water, gas and heat enterprises are responsible for digitally upgrading the existing mechanical metering and new residential communities, realizing the remote transmission of energy measurement data, and then sharing the energy measurement data according to a certain proportion. Free sharing mode refers to Internet thinking, due to low initial investment, widely

Water, gas, and heat companies are welcome, and energy metering data is proportionally shared. The single-family acquisition price that significantly reduces energy data can help grid companies to rapidly increase their market share in the field of energy metering and integration, and then tap energy measurement data. Value, through the value-added services to achieve profitability.

Bills can be divided into joint bills and separate bills. For customers whose bills are issued at the same time, the grid company issues a joint payment notice for electricity, water, gas and heat utilities (hereinafter referred to as the joint bill).

The three conditions of meter reading cycle, meter reading day, and post-paid cannot be satisfied at the same time. Electricity, water, gas, and heat separately send payment notices according to their own business needs.

The water, gas and heat companies push their respective accounts receivable information to the real-time after the respective receivable data is generated.

On behalf of the copying system, on behalf of the copying system to generate energy metering integration collection public utility joint payment notice. The notice contains the billing information of the customer's electricity, water, gas and heat, and generates the QR code or billing barcode of the e-po, which is convenient for the customer to choose one-time payment or separate payment through online and offline channels.
The joint bill is pushed by the grid company, and the electronic push method is preferred. Power grid enterprises push electronic billing information notifications through e-po, handheld power, and various WeChat platforms to remind customers to view bill details on their online platforms. For some customers who are accustomed to accept paper bills that are difficult to change, they can temporarily adopt paper bills and simultaneously push the experience of electronic bills, gradually change their habits, and finally realize full electronic bills [6].

When the customer charges through the electricity, water, gas and heat independent system, the charging information should be pushed to the copying system in real time, and the sales processing of the copying system should be completed, avoiding the repeated charging of the system and the separate systems of electricity, water, gas and heat.

The charging is mainly realized through two channels. The first is the offline charging channel, which mainly includes the power self-service terminal and the electric power business hall. The second is the online electronic charging channel, which mainly includes the self-owned electronic charging method of the power grid enterprise. There are 95,598 websites, handheld power, and e-bao.

3.2. **Mining data value.** Collecting electricity, water, gas, and heat meter reading data, and constructing a data analysis model, can provide various types of analysis and energy recommendation services for energy users, energy companies, and governments.

3.2.1. **Energy structure analysis.** Based on electricity, water, gas, heat monthly usage and electricity, water, gas, thermal energy ladder unit price, provide energy consumption structure map for each household, let residents intuitively grasp the energy use situation, and pass The cell classification guides users to save energy and reduce consumption by ranking the energy costs [7].

3.2.2. **Comprehensive energy planning.** Based on the local electricity, water, gas, and heat ladder rates, the unit energy consumption information of different energy sources of electricity, heat, and gas, and the historical energy use of the user, the minimum cost for the user to plan the same energy consumption. The combination of energy use mode optimizes the energy structure for the user. After collecting the information of the user's household appliances, the user can further provide suggestions for the user's energy behavior such as peak power consumption, and guide the user to develop a habit of saving energy.

3.2.3. **Integrated energy service for large industrial users.** Deeply involved in the production process of industrial users, based on industrial product production process and production process, calculate the information of electric water and gas heat consumption of individual products, and propose energy alternatives to optimize the production energy consumption ratio.

3.2.4. **Analysis of regional energy level.** Based on the energy curve of regional electric water and gas, the energy prediction model is constructed to predict the overall trend of energy use in the jurisdiction, and the government provides energy planning recommendations based on the forecast.

3.2.5. **Analysis of housing vacancy rate.** Based on the combined data of electricity, water, gas and heat, the vacant house analysis model is constructed, and the vacant households with zero daily residential energy consumption in the city are divided into time-division statistics to provide the government with various districts in the city. The vacancy rate comparison and the vacancy rate are the same as the ring ratio, which is convenient for the government to formulate the corresponding urban supporting facilities plan according to the vacancy rate change. For example, in the residential areas with low vacancy rate and low consumption level, the commercial, road and traffic indicator planning is increased, and the vacancy rate is high. In the residential areas with high consumption levels, plans for medical care and national fitness equipment will be increased.
3.2.6. **Analysis of typical energy use of holidays.** Analysis of energy use in rural areas and cities according to time series. According to changes in energy consumption in cities during holidays, cities (counties) are divided into tourist cities, ordinary cities, returning cities, etc. The city type and population movements are formulated accordingly.

3.2.7. **Analysis of urban industrial energy use.** According to the standard coal conversion amount corresponding to unit electricity, gas and heat energy, industrial pollution discharge (carbon dioxide, sulfur dioxide, solid particulate matter, etc.) per unit standard coal, the overall electricity, gas and heat use of the city, Calculate the city's comprehensive energy pollution emissions, and lay the foundation for the government to formulate policies to optimize energy use structure and control environmental pollution.

4. **Conclusion**
With the continuous deepening of the construction of energy Internet, all kinds of energy metering technologies will be developed in the direction of intelligence, automation and interaction, providing quality services for the communication between energy companies and residents, and achieving electricity, water, gas and heat. Reliable measurement of energy sources. In order to adapt to this development trend, the project will further explore the system architecture system covering emerging services such as distributed power supply, electric vehicle charging and replacing, and customer side energy storage, laying a foundation for the healthy and orderly construction of energy metering integration in China.

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