Construction of IoT management system for intelligent monitoring of distribution room

Wenjie Ma¹*, Yanru Wang¹, Wenjing Guo², La Bao³, Rui She¹
¹Beijing Fibrlink Communications Co., Ltd., Beijing, 100070, China
²State Grid Information & Telecommunication Group Co., Ltd., Beijing, 102211, China
³Beijing Zhongdian Derui Electronic Technology Co., Ltd., Beijing, 100041, China
mawenjie@sgitg.sgcc.com.cn

Abstract. In order to further improve the quality and efficiency of distribution network operation and maintenance work, and support the transformation of distribution network technology to digital, lean, and intelligent, this article proposes an IoT management system for intelligent monitoring of power distribution rooms, as well as a design plan for IoT management platforms and edge IoT agents. It also conducts key research on the environmental information monitoring and perception system of the power distribution room, the power protection and security perception system, and establishes an intelligent and visualized intelligent distribution room to realize the digital transformation and intelligent improvement of the operation and maintenance of the power distribution network. The results are applied in the construction of Zhejiang intelligent distribution room, providing important guidance for the standardized construction of intelligent distribution room in China.

1. Introduction
As an important part of the power system, the distribution network is closely connected with power users. The distribution room is an important part of the distribution network, and its management system construction directly affects the reliable operation of the distribution network. Over the years, the monitoring of power distribution rooms has mainly relied on regular inspections by operation and maintenance personnel, which is time-consuming and labor-intensive. There are problems such as insufficient operation and maintenance personnel, uneven comprehensive quality, and failure to find and deal with failures in time, which directly endangers the reliable operation of equipment and causes failure of electricity, equipment damage, and equipment theft[1]. Aiming at the problems of incomplete perception of power distribution rooms and low degree of automation of operation and inspection, this article designs an IoT management system for intelligent monitoring of power distribution rooms, focusing on solving the ubiquitous IoT, data perception, and Unify management issues among power equipment in the power distribution room, effectively integrate environmental information monitoring, power protection and security monitoring systems, and effectively improve the intelligent operation and maintenance level of the power distribution rooms, and provide a guarantee for safer and smarter power supply.
2. The design scheme of IoT management system

The IoT management system for intelligent monitoring of power distribution rooms applies advanced technologies such as the Internet of Things, artificial intelligence, digital twins, and big data analysis, combined with the construction requirements of the power Internet of Things, and adopts a multi-layer system architecture "separation of side and end, sharing of side and management "[2]. The system architecture is shown in Figure 1, supporting the IoT application of "regional collection + centralized control + edge autonomy".

![Figure 1 IoT management system architecture for intelligent monitoring of power distribution rooms](image)

On the "end" side, the perception layer, the distribution room is an important scene for the construction of the power Internet of Things. Its IoT perception system construction generally includes two parts: environment perception and power protection and security perception, and supports the access of temperature sensors, cameras, inspection robots, smoke sensors, access control and other sensing devices.

On the "side" side, the edge IoT agent, the "important hub" between the local communication network and the wide area communication network in the power Internet of Things is used to connect the business terminal and the platform layer to achieve network edge intelligence[3].

On the "management" side, the IoT management platform, it realizes unified management of edge IoT agents and sensing terminals. At the same time, the standardized business data is forwarded to the business middle station and the data middle station to provide data support for the upper application system.

3. IoT Management Platform

The IoT management platform provides capabilities such as device security access, message parallel computing, smart device life cycle management and control, and one-stop IoT application management. The IoT management platform realizes the access and data standardization of power distribution room service terminals and edge IoT agents, empowers smart terminals, accelerates comprehensive perception, supports platform sharing upwards, realizes data and business integration, and drives innovation capabilities. The IoT management platform is based on a distributed architecture design, based on "cloud-fog collaborative" computing, developed using a microservice architecture[4], and based on
Kafka, Flink, ElasticSearch and other middleware to achieve high-throughput quasi-real-time data processing capabilities, seamless with data center integrated.

**Connection management:** the IoT management platform is based on the Erlang/OTP platform and supports carrier-class network parallel processing capabilities; the platform adopts the Internet of Things MQTT messaging service with a distributed cluster architecture, which carries the MQTT connections of massive Internet of Things terminals; The platform adopts a plug-in structure to support protocol analysis, message processing, message filtering and other functional extensions.

**Device authentication:** the platform registers all connected devices, provides secure access authentication functions, and implements secure encrypted communication after device authentication. By issuing device identity certificates or keys, the identity of the networked device is guaranteed to be legal, and illegal access to the device is prohibited.

**Message management:** the platform provides low-latency, high-throughput, and customizable parallel processing capabilities for streaming data, allowing users to customize rule algorithms according to business needs, and the calculation results can be automatically identified and distributed according to the rules.

**Device management:** the platform realizes unified management of IoT terminals and edge IoT agents, and functions include device registration, device configuration, device topology, edge computing management, object model, device shadow, device monitoring, device maintenance, device logs, etc.

**Application management:** the platform supports operations such as downloading, installing, deleting, viewing, online starting and stopping of applications in the edge IoT agent; it supports real-time monitoring of the status of applications in edge IoT agents, including startup and shutdown status, application version, CPU usage, memory usage, and disk space usage.

**Operation and maintenance:** the platform builds a log aggregation platform, a performance monitoring platform, integrates an open source micro-service engine, provides a northbound open interface, realizes application enablement, and provides a comprehensive guarantee for the operation and maintenance of the micro-platform.

![Functional architecture of IoT management platform](image)
4. Edge IoT agent

Edge IoT agent supports unified access and management of different types of sensing devices in the power distribution room, and has functions such as protocol adaptation, data collection, and cloud-side collaboration. At the same time, edge IoT agent is generally deployed close to IoT sensing terminals, which can realize on-site computing and regional autonomy of business data. Edge IoT agent can handle alarms and faults that need to be responded to in time, effectively alleviating the burden and pressure of network communication, data storage and computing processing of the IoT management platform, and avoiding resource waste and response delay caused by massive data uploading to the cloud.

**Figure 3** Functional architecture of Edge IoT agent

**Customized design:** edge IoT agent introduces modular design concepts and container technology[5], and can flexibly customize software and hardware modules to meet the plug-and-play needs of intelligent monitoring services in power distribution rooms.

**Intelligent communication:** edge IoT agent supports multiple communication technologies such as wired, wireless, ZigBee and LoRa, and supports redundant backup of communication links to improve the reliability of data transmission at the end. The edge IoT agent judges the terminal communication status in real time, dynamically switches the main and standby communication modes, and implements the corresponding information security protection strategy to ensure the stable and reliable access of the terminal.

**Protocol adaptation:** edge IoT agent flexibly implements application innovation and new protocol deployment, supports 101, 104, 61850 and other series of protocols and specifications, and 698, 645, 1376, MQTT and other protocols to meet terminal device holographic sensing access and unified data collection.

**Multi-source access:** edge IoT agent adapts to a variety of general protocols and power proprietary protocols, and carry diversified local communication methods to achieve access to multiple types of terminals including mobile phone terminals, inspection robots, and IoT sensor terminals.

**Edge computing:** edge IoT agent is based on massive location, terminal, user behavior data and a powerful background analysis system, equipped with a high-speed processing platform, has big data analysis and edge computing capabilities, and meets the needs of intelligent processing of business
terminal data. Edge IoT agent can realize the correlation analysis and on-site processing of device multi-source information in the application area, and realize regional autonomy[6].

Cloud-side collaboration: edge IoT agent supports interaction with the IoT management platform to realize a cloud-side collaboration system covering resource collaboration, data collaboration, application management collaboration, and business management collaboration.

5. IoT management system

5.1. Environmental information monitoring and perception system
The perception system collects environmental information in the power distribution room by deploying various end-sensing terminals such as temperature and humidity, fire smoke detection, one-key alarm, harmful gas, equipment flooding, and groove water level, so as to realize online refined management of multi-dimensional environmental parameters in the power distribution room[7]. The perception system relies on the environmental information collected in the power distribution room, and based on the analysis of historical data of fire prediction, water level monitoring, toxic and hazardous gas monitoring, and temperature and humidity monitoring, sets the monitoring parameter thresholds of the power distribution room. The perception system uses thresholds to determine whether there are external intrusions, fires, harmful gases, and water accumulations in the distribution room, and simultaneously sends the risk warning information to the mobile APP of operation and maintenance personnel to provide guarantee for the timely detection and disposal of defects and hidden dangers in the distribution room[8].

5.2. Power protection and security perception system
The power distribution room protection security perception system, relying on inspection robots, video surveillance, biological access control and other perception devices, creates a power protection security architecture with accurate detection and intelligent identification from three aspects: equipment operation, power distribution room environment and personnel management[9]. The inspection robot integrates infrared temperature measurement and partial discharge monitoring, performs inspection and meter reading operations through visible light images, completes various dial text recognition, and simultaneously detects equipment temperature and partial discharge conditions, and efficiently collects equipment working condition information[10]; Video surveillance can monitor the current operating conditions of the power distribution room in real time, combined with image recognition technology to achieve functions such as intrusion, motion detection, smoke recognition, and fire identification, so as to facilitate the personnel to investigate abnormal conditions generated during the operation of the power distribution room; The biometric access control has the function of face recognition, realizing personnel identification and authentication processing.

6. App validation
Relying on the IoT management system for intelligent monitoring of power distribution rooms constructed in this article, the country’s first fully-sensing smart power distribution room was built in Zhejiang. The full-sensing intelligent power distribution room is equipped with edge IoT agent devices and IoT management platform, adopts wireless multi-hop ad hoc network technology, and uses biometric access control, intelligent monitoring, intelligent inspection robots, wireless environment sensing terminals, ozone sensors and other intelligence Perception equipment to realize holographic perception, self-service research and judgment, and precise control. When the data collected by the device terminal of the perception layer exceeds the threshold range, the system will promptly give an alarm of abnormal conditions to ensure the safe and reliable operation of the power distribution room. At the same time, the collected data will be used as a basic resource for big data analysis and processing to realize early warning.

The full-aware power distribution room increases the perception ability of the power distribution room to 100%, saves 67% of operation and maintenance costs, effectively improves the lean management level of the power grid, and improves the power supply service capability.


7. Summary
This article builds an IoT management system for intelligent monitoring of power distribution rooms based on the research of IoT management platforms and edge IoT agents, and relying on the environmental information monitoring of power distribution rooms, power security and other sensing devices. Through the Internet of Things management system, real-time monitoring of images and data in the power distribution room can be realized, breaking the data barriers between systems, realizing data sharing, improving the intelligence level of the power distribution room, reducing the intensity of operation and maintenance personnel, and ensuring the safety and reliability of the operation and maintenance of the power distribution room.

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