Research on Data Acquisition Technology of Distribution Automation Based on Internet of Things Communication Protocol

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Abstract: With the gradual application of the Internet of Things technology in the field of distribution automation, distribution terminals gradually adopt the Internet of Things protocol to communicate with the master station system of distribution automation. While the master station system of distribution automation supports the access of the traditional power dedicated protocol terminal, it faces how to solve the problem which how to access the distribution terminal of the network communication protocol. This paper proposes the MQTT protocol data acquisition architecture based on the existing master station system of distribution automation system. Through the research on the transmission characteristics of power distribution service data and MQTT protocol, the message structure of the MQTT protocol carrying power service data and the source maintenance process of the equipment model are designed. It realizes the direct collection of the terminal data of the distribution Internet of Things in an object-oriented way, gives full play to the value of the existing distribution master station, reduces investment costs, and saves system maintenance workload.

1. Introduction
The low-voltage distribution network is at the end of the power system, directly undertaking the power supply tasks of grid users, and is a key link that affects the level of power supply services. For a long time, the low-voltage distribution network has lagging behind in automation, and at the same time it faces the challenges of rapid changes in management requirements, large-scale management equipment, and high service requirements \cite{1}. In recent years, with the massive access of electric vehicles, distributed energy sources, micro grids, energy storage devices and other facilities, higher requirements have been placed on the automation level of low-voltage distribution networks \cite{2}.

To improve the automation level of the low-voltage power distribution network, communication protocols are the key link. Traditional power communication protocols face a wide variety of terminal equipment problems, lack effective solutions, equipment access and business applications are subject to many restrictions, at the same time traditional The electric power communication protocol is not an object-oriented protocol, and a lot of work is added when terminal equipment is connected, which cannot meet the needs of fast access and plug-and-play of mass equipment \cite{3-4}. Distribution Internet of Things is a new type of power distribution network form produced by the deep integration of power distribution technology and Internet of Things technology. Through the interconnection and intercommunication of low-voltage equipment in the distribution network, comprehensive perception,
With the gradual application of Internet of Things technology in the field of power distribution, new power distribution terminals have gradually developed into Internet of Things terminals, using Internet of Things protocols to send data, and deploying an Internet of Things management platform at the cloud master station to be specifically responsible for accessing such terminal devices. The master station system of distribution automation obtains the data of the IoT terminal through the IoT management platform. Due to the large investment and long construction period of the IoT management platform, the existing master station system of distribution automation does not support direct access to the power distribution through the IoT protocol Terminals, causing some power distribution Internet of Things terminals to fail to connect to the main station in time, affecting the construction progress of the power distribution automation system.

This paper proposes to expand the communication protocol library in the master station system. Through the analysis and application research of the characteristics of the Internet of Things communication protocol MQTT, it realizes the direct collection of the data of the power distribution Internet of Things terminal, and gives full play to the value of the existing master station system of distribution automation, reducing investment costs and saving system maintenance workload.

2. The communication mechanism of MQTT protocol

2.1. The features of MQTT protocol

MQTT, released by IBM in 1999, is a lightweight communication protocol based on the Publish/Subscribe mode, and its message header has a minimum of 2 bytes. The message body is binary and compact, which is very suitable for the resource-constrained Internet of Things field. It can provide real-time and reliable message services for remote devices with very few codes and limited bandwidth. MQTT is used in Internet of Things, small devices, and mobile applications. It has a wide range of applications. The protocol runs on TCP/IP's orderly, reliable, and bidirectional network connection.

2.2. The communication model of MQTT protocol

The MQTT protocol supports point-to-point, group sending, group sending and other message interaction scenarios through topic-based subscription/publishing modes. The message routing method is flexible, the message body is in binary form, and the message format can be customized for each business scenario, which realizes message distribution and application. Decoupling between Message distribution does not need to know the payload content. There are three identities in the MQTT protocol: Publisher, Broker, and Subscriber. Among them, the publisher and subscriber of the message are both clients, the message broker is the server, and the message publisher can be the subscriber at the same time. The communication process is shown in the following figure:

Fig. 1 The MQTT protocol communication process
When sending data, it sends data as a publisher, and when receiving data, it receives data as a subscriber. MQTT proxy is similar to the role of a post office or messenger. Its main function is to receive network connections from the client and receive messages published by the client. Application messages, processing client subscription and unsubscription requests, forwarding application messages to eligible client subscriptions, etc.

3. The MQTT data acquisition architecture of the master station system of distribution automation

The data acquisition function of the master station system of distribution automation is mainly responsible for the real-time data communication processing tasks between the power grid monitoring center and the power distribution terminal. The basic tasks include information exchange, command transmission, protocol organization and interpretation, channel encoding and decoding, and satellite Time synchronization, reasonable allocation of acquisition resources, etc.. the master station system of distribution automation converts the terminal data of different communication protocols and different data types into the internal data format of the master station system in advance to provide real-time data for the application functions of the master station.

3.1. The data acquisition software architecture of MQTT

The data acquisition function is composed of functional modules such as parameter management, collection task management, communication management, protocol processing, and data interaction. The parameter management module realizes the synchronization management of the parameters of data acquisition, and performs parameter synchronization in time. the collection task management module makes comprehensive judgments according to the collection server status, process status, and channel status, and manages the results of multiple machines, multiple channels, and multiple sources. data interaction module Realize the interaction of data and control commands between front and backend.

data acquisition man-machine service provides manual operation interface for automation personnel to maintain and monitor the collection function. traditional protocol processing module converts data and control commands according to the configuration definition of different protocols. The above modules cooperate with each other to complete the data acquisition of the traditional power distribution terminal.

![Fig. 2 The software architecture diagram](image-url)
The Internet of Things MQTT protocol data acquisition is based on the original collection function, adding MQTT proxy module and Internet of Things protocol processing module to realize data acquisition on Internet of Things power distribution terminals. The MQTT proxy module uses Mosquitto middleware, which mainly implements TCP link management and the publishing/subscription of MQTT messages. The IoT protocol processing module parses out the power business data according to the definition of the MQTT message format and sends it to the data exchange module or exchanges data from it. The module obtains the master station's downlink control information and converts it into an MQTT protocol message and sends it to the MQTT agent. The detailed software architecture is shown in the figure below.

3.2. The MQTT data flow of master station system of distribution automation

The field Internet of Things power distribution terminal data is sent to the main station data acquisition software in the form of MQTT messages via the remote network. The data acquisition software converts the MQTT messages into a unified data format inside the system and sends them to the main station background application. The specific data flow is shown in the figure below:

1) Before the Internet of Things terminal is connected to the main station system, it needs to provide the terminal's own ledger information and object model files, which are imported to the main station system by the parameter management module of the data acquisition software.

2) Each time before the Internet of Things terminal goes online, first access the collection task management module to obtain the IP address and communication port of the front-end processor to be connected.

3) After the IoT terminal obtains the communication parameters, it actively connects to the MQTT proxy module of the front-end processor through the MQTT connection message.

4) The IoT terminal encapsulates the real-time data of the device into an MQTT message and publishes it to the MQTT proxy module in front of the master station.

Fig. 3 MQTT protocol data flow diagram of distribution master station
(5) The IoT protocol processing module cyclically subscribes to the MQTT message sent from the terminal from the MQTT module, and parses the real-time data from the message according to the protocol structure, and simultaneously receives the real-time data and writes it into the data buffer queue.

(6) The front-end and back-end data interaction module reads the business data from the real-time data buffer queue, converts it into a unified data format inside the system, and sends it to the message bus. The back-end application obtains the real-time data of the entire network from the message bus to complete various business analysis Processing function to realize real-time monitoring of the entire power grid.

4. The key technologies for data acquisition of IoT MQTT

The MQTT protocol is not a transmission protocol designed for the power industry. The protocol does not define the format of business data messages and cannot be directly applied to the power distribution automation system. Compared with the traditional power communication protocol IEC104 protocol, the MQTT protocol does not have the concept of a point table. The master station system of distribution automation system cannot continue to be used by linking the primary and secondary equipment of the power system through the point table. The application of the Internet of Things MQTT protocol to realize the collection of power distribution automation data requires the following key technologies to be solved.

4.1. The message structure of distribution

The MQTT protocol classifies messages by topics. In order to avoid mutual interference between messages, the distribution automation master station assigns three topics to each terminal in advance. The first topic is defined as /device/data/{termId}, where termId is the ID number of the terminal itself is used for the power distribution terminal to send power business data and the platform to receive the data. The second topic is defined as /device/command/{termId}, which is used for the master station to send control commands in advance, and the power distribution terminal to receive the master Station command. The third topic is defined as /device/response/{termId}, which is used for the power distribution terminal to send the response master station command message, and the master station receives the command response message. If there are N power distribution terminals in a power distribution automation system, the total number of topics needs to be set to 3N. Each terminal needs to subscribe to one topic and publish two topics. and the master station system of distribution automation needs to subscribe to the topics published by 2N terminals and publish N topics for different power distribution terminals.

The distribution business data message structure adopts the object-oriented description method to directly transmit the object-oriented data. The distribution master station can directly identify the specific business information after receiving the MQTT message, without the need to analyze the data through the point table like the traditional power communication protocol. It saves a lot of work of checking information point by point between the master station and the terminal. The distribution service data message structure mainly includes three levels of equipment, measurement type, and data value to represent real-time data. For example, the A-phase voltage value of a switch is 10.56, the B-item voltage is 10.24, the switch state is closed, and the description of the message structure as follows:
4.2. Device model source maintenance

The MQTT protocol of the Internet of Things uses an object-oriented way to transmit real-time data. How the master station system of distribution automation and the power distribution terminal use a common device model is the key to realize the plug-and-play access of the IoT terminal. The collection object of the low-voltage distribution network is mainly the distribution transformer station area. The inside of the station area includes various traditional measurement and control devices such as low-voltage branch switches, concentrators, smart meters, and low-voltage fault indicators, as well as new types of power stations such as charging piles and photovoltaics. Electrical equipment. The equipment model maintained at the source end includes the primary power equipment model, the secondary sensor equipment model, the primary equipment model and the secondary equipment model association relationship in the station area.

The sensor device ID is managed uniformly in the asset management system (PMS system), and the GIS system is obtained from the asset management system and is guaranteed to be unique. The source of source maintenance is in the GIS system, and the primary device topology in the GIS comes from the design and construction drawings. Any changes to the primary or secondary equipment in the district should be maintained in the GIS first, and the correctness of the topology should be ensured. In the GIS, the primary equipment is manually associated with the corresponding sensor device ID, and the information flow is transferred to the master station system of distribution automation system, and the master station system of distribution automation system Distribute the archives of the station area to the station area power distribution terminal, and finally realize the unification of the model between the main distribution station and the terminal. The source-side maintenance process of the equipment model is shown in the following figure:

Fig. 4 MQTT message payload data structure
5. The MQTT protocol data acquisition test
In order to test the feasibility of the traditional master station system of distribution automation to collect data through the Internet of Things MQTT protocol, a test environment as shown in Figure 4 was built. The main equipment of the test environment includes 2 PC servers, 2 IoT terminal stations, and 1 switch.

| SN | Device Name | Model and configuration |
|----|-------------|-------------------------|
| 1  | MQTT broker | CPU: Intel Xeon CPU E7-4820 v2  
      |              | RAM: 64GB                
      |              | operating system: Linux 3.10.0-862.el7.x86_64 |
The master station system of distribution automation selects a PC server, deploys the OPEN5200 master station system of distribution automation development platform, and enables applications such as DB_SERVICE, PUBLIC, SCADA, FES. MQTT proxy server deploys Mosquitto message agent. Power distribution terminal selects smart station terminals that support MQTT protocol.

In the test process, the process of importing the CIM model from the GIS system is simplified, and the primary equipment model and sensor equipment model of the grid area are manually entered directly at the master distribution station, and the association between the primary equipment and the sensor secondary equipment is completed. The station area terminal actively connects to the collection task management module in front of the master station, obtains the IP address and communication port of the MQTT proxy server, and downloads the sensor device model of the station area. The station area terminal organizes real-time data based on the sensor device model. An object-oriented MQTT message structure is published to the MQTT proxy server. The front-end server cyclically subscribes MQTT messages to the MQTT proxy server to complete the data acquisition of the terminal in the station area. As the master station eliminates the need for meter maintenance work, the average access time of the two smart terminal stations has been prompted from 2 hours to 15 minutes, and the access efficiency is increased by about 90%.

6. Conclusion

The State Grid Corporation of China is vigorously promoting the development and construction of the power Internet of Things. The power distribution field is directly related to users in the "generation, transmission, transformation and distribution". The construction of the Internet of Things in the field of power distribution is the key to the real realization of the Internet of Things in the entire power grid. The application of the Internet of Things MQTT protocol to the power distribution automation system has significantly improved the flexibility and access efficiency of various power equipment data access, and solved the inconsistent access protocols of various terminal equipment such as video monitoring, temperature and humidity collectors, and capacitor equipment. At the same time, it reduces the workload of operation and maintenance personnel and improves the level of distribution automation operation management. However, the MQTT protocol is not a dedicated communication protocol for the power system. The business characteristics of the power system are not considered enough. The master station system and terminal devices must be adapted and modified. Further research is needed to increase the automatic conversion technology of the power equipment model to the MQTT message format. Gradually promote the promotion and application of the MQTT protocol in the power industry.

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