Design of Distribution Equipment Monitoring System Based on Internet of Things and Multi-Agent

Ruide Li1a*, Guowei Wang1b*, Wenxia Dai1c, Xinyu Zan2d, Tiefeng Zhang2e
1 Jiangmen Power Supply Bureau of Guangdong Power Grid Co, Ltd, Jiangmen 529000, China
2 School of Electrical and Electronic Engineer, North China Electric Power University, Baoding 071003, China
a*1125893346@qq.com, b*85210440@qq.com, c12525491@qq.com, d13833717353@163.com, ecepuztf@126.com

Abstract—In order to improve distribution equipment reliability and emergency repair response speed, a distribution equipment monitoring system based on Internet of things and multi-agent is designed by building a hierarchical model. The system is based on the power Internet of things, which is divided into sensing layer, device layer and data center layer. The sensing layer realizes multi-source data acquisition through sensors and acquisition devices; the device layer deploys edge computing agents to realize device-level monitoring; and the data center layer deploys coordinating agents to realize system-level analysis. The dual-way communication is used to realize data transmission between up layer and down layer. The system has the characteristics of distribution, autonomy and multi-objective interaction, which can meet and adapt to the demand and development trend of intelligent operation and maintenance of distribution equipment.

1. Introduction
Distribution equipment such as transformer, switch cabinet and cable has the characteristics of many types, large quantity and wide distribution. In the process of its use, it is affected by environmental high temperature, high humidity, overload and equipment quality, leading to the decline of insulation performance. At the same time, cold and heat changes, material aging, corrosion, looseness and other reasons can easily cause poor contact, induce thermal failure of the equipment, and burn the equipment when high current passes, or even catch fire and explosion. Existing monitoring system is mostly based on single equipment, poor scalability, flexibility, versatility, and independent among monitoring system, even for similar equipment monitoring system cannot effectively achieve information transformation and sharing, the information island greatly limits the application range of the monitoring system, and causes great waste of resources [1]. Therefore, it is urgent to design a real-time automatic monitoring system for distribution equipment.

In recent years, more and more researchers have paid attention to the application of multi-agents in various industries. In [2], multi-agent technology is applied to the fault recovery of ship integrated power system, which can solve the problem of fault recovery of ship integrated power system quickly and effectively. The authors apply multi-agent theory to the field of nursing, and finds the best solution at low cost through agent collaborative simulation in [3]. The authors build an active distribution network distributed energy coordination control architecture based on a multi-agent system to support the joint optimal dispatch of multiple distributed power sources in [4]. A network selection method MQSM based
on multi-agent Q-learning is proposed to improve the resource utilization of heterogeneous vehicle networks while ensuring a good QoS experience for vehicle end users in [5]. Aiming at the application scenarios of digital twin technology in different fields at home and abroad, a smart micro-grid digital twin and multi-agent control architecture that considers the interaction of multiple communication protocols is designed, which improves the self-sensing, self-predicting and adaptive capabilities of the smart micro-grid in [6]. In order to solve the dynamic scheduling problem of textile fabric dyeing workshop in which tasks arrive dynamically with orders, a fully reactive scheduling method based on multi-agent cyclic near-end strategy optimization reinforcement learning is proposed, which can effectively reduce the total delay time of products and improve the on-time delivery ability of orders in [7].

The current power distribution equipment monitoring has already used the power Internet of things technology, and the related system is a typical distributed structure. If the idea of multi-agent is further introduced into the power distribution equipment monitoring system, the efficiency of monitoring can be improved. This paper introduces multi-agent technology with the characteristics of autonomy, collaboration, and interactivity, builds a hierarchical model of monitoring system based on the Internet of things and multi-agent, designs a multi-agent cooperation process to realize real-time monitoring of power distribution equipment, so as to avoid safety hazards and economic losses caused by equipment failures.

2. Multi-Agent System
The concept of agent originated from artificial intelligence, which is a computer system in a certain environment, which can be hardware or software, and can operate flexibly and autonomously in the environment. Agents have the characteristics of autonomy, sociality, reactivity, initiative, mobility and communication ability [8].

Multi-agent system is a system composed of multiple agents, which is to solve complex problems that cannot be solved by a single agent. And it is a solution network of problems formed by coordination and cooperation of multiple agents. The multi-agent system not only has the characteristics of an agent, but also has the characteristics of distributed data calculation, asynchronous process and concurrency.

3. Hierarchical Model of Power Distribution Equipment Monitoring System Based on Internet of Things and Multi-Agent
The power Internet of Things is usually divided into the sensing layer, the network layer, and the application layer, which are responsible for sensing execution, data transmission, and application analysis tasks. In order to reduce the scale of data transmission, the application layer functions will be deployed on edge proxy servers and data center servers, causing the computation and data processing work to sink. After the introduction of the agent, this paper divides the system into the sensing layer, the device layer and the data center layer based on the monitoring structure of the power Internet of things equipment. The sensing layer realizes multi-source data collection through sensing and acquisition devices, mainly collecting high and low voltage wiring temperature, iron core ground current, temperature and humidity, to provide data information for device-level monitoring. Edge computing agents are deployed in the device layer to realize device-level monitoring through the agent, and the main objects include distribution transformers, switchgear (ring network cabinet), distribution (cable ditch) cables. The data center layer deploys coordination and decision-making agents to realize system-level monitoring, including management agents for managing scheduling information and decision-making agents for evaluation and decision-making, to achieve system-level analysis. The two-way communication technology is used to realize data transmission between each layer. The hierarchical model of the distribution equipment monitoring system based on the Internet of things and multi-agents is shown in Fig 1.
4. Design of Monitoring System for Distribution Equipment Based on Multi-Agent

4.1. Design of Edge Agent at Device Layer

The device layer deploys the edge processing unit, realizes the collection and processing of the sensing information of each distribution device condition in the sensing layer, and completes the monitoring function of the device. Information from the various sensors and data acquisition devices is integrated and fused here to support the comprehensive status assessment of the monitoring equipment. The data sources of the edge processing unit are shown in Fig 2. The device completes corresponding functions by deploying edge agents.

Since the edge processing unit is applied to different power distribution equipment in the power distribution system, in order to realize the autonomy and scalability of the edge processing unit, this paper designs the software part of the edge processing unit based on multi-agents. In this paper, the edge processing unit based on multi-agent mainly includes three parts: system agent, knowledge agent and executive agent. Among them, the system agent is mainly responsible for the start and resource allocation of the whole distribution network monitoring system to ensure the normal operation of the monitoring system; The knowledge agent is responsible for interacting with each module of the edge processing unit system, including data acquisition module, algorithm module, communication module, etc., and providing corresponding parameters and models for each module to support the implementation of the work of the agent; the executive agent is the most important agent in the edge processing unit, and it is the bridge connecting the system agent and the knowledge agent. The cooperation process of agents in edge processing unit is shown in Fig 3.
4.2. Data Center Layer Agent Design

In this paper, the system-level agent is the management center for monitoring the whole distribution system, which is the highest human-computer interaction platform. The system-level agent works as follows: Firstly, the man-machine interface is used to configure the monitoring points, that is, the address information of each monitoring point is registered, and the configuration instructions are interoperated.
with the system agent of the edge processing unit for data processing. Then, through the implementation of the monitoring process, the performance monitoring information of all distribution equipment is integrated to give the overall operating condition information of the equipment, and the human-machine interface is used to interact with the technical personnel to develop the equipment maintenance plan. The system-level agent mainly includes two parts: the management agent and the decision agent.

The function of management agent is to connect different agents and provide a public environment for the interaction between different agents, which is the key link to realize effective interaction of monitoring system. The management agent stores the address recognition information of all the agents and can give feedback to the interaction requirements of each agent in time. At the same time, managing agent can write new agent address information or clear the agent address information which is no longer needed by the system, so that the whole system has a good openness. The management agent consists of two different communication modules and one interactive demand judgment module. The interactive demand judgment module mainly identifies the address information of data, discriminates the destination of information transmission, carries out target matching, and gives it to the corresponding agent. Based on the above structure, the management agent performs coordination between different agents.

After receiving the request of each intelligent sensor, the management agent notifies the decision-making agent. After receiving the notification, the decision-making agent can obtain the status information of each distribution equipment, and carry out the health diagnosis at the device-level and system level. Meanwhile, the status information is stored in the database to provide the basis for the maintenance plan formulation.

Database is the basis and foundation for comprehensive decision-making. It describes condition information from different sources and levels with a unified information specification. When the system-level monitoring setting is completed, the address information of each agent has been submitted to the database. Oracle not only has complete data management function, it is also a distributed database system that supports various distributed functions. And it has good compatibility, portability, connectability, high productivity, openness and so on. Therefore, the data center layer uses Oracle. The decision-making agent can monitor the whole health of the power distribution system by calling the information in the database and using certain decision methods.

### 4.3. System Construction and Workflow

This paper takes distribution transformer monitoring as an example. The information can be used to evaluate the health condition of the transformer through the data acquisition of the sensor and the acquisition device on the key position of the transformer. The system in this case consists of a data center responsible for remote monitoring and management, remote mobile terminal receivers, edge processing units, and monitored equipment. The system composition is shown in Fig 4.

### 4.4. Equipment Condition Evaluation

The edge processing unit uses machine learning algorithm to evaluate and analyze the collected device data for a single device and uploads the results to the data center. The data center conducts summary analysis and overall evaluation of various types of devices. The main application of learning algorithms includes time series and support vector machine [9], fuzzy support vector machine algorithm [10], deep learning for the Internet of things with edge computing [11], rectified linear units deep belief network [12], deep convolutional neural network [13] and so on.

Arrange scientific maintenance strategies for operation and maintenance personnel according to the severity of faults, so as to improve work efficiency. In this paper, the equipment condition evaluation is divided into four conditions, that is, normal condition, attention condition, abnormal condition and serious condition.

- **Normal condition**: It means that each condition quantity of the equipment is stable and within the warning value and attention value stipulated in the regulations, and it can operate normally.
• Attention condition: The single (or multiple) condition quantity changes towards the direction of close to the standard limit, but does not exceed the standard limit, the operation can still continue, and the monitoring in operation should be strengthened.

• Abnormal status: The single important status variable has changed greatly, and it has approached or slightly exceeded the standard limit. The operation should be monitored, corresponding treatment measures should be taken, or power outage maintenance should be arranged in a timely manner.

• Serious condition: The single important condition quantity seriously exceeds the standard limit, and it is necessary to arrange power outage maintenance as soon as possible.

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5. Application Effect
The multi-agent-based power distribution equipment monitoring system uses multi-agent technology to integrate multiple fault diagnosis and condition evaluation algorithms, and comprehensively conducts condition evaluation through data information collected by intelligent sensors. Taking distribution transformer as an example, transformer fault diagnosis is based on data and information such as high/low voltage wiring temperature, low voltage three-phase current, vibration of body, grounding current of iron core, temperature and humidity collected by intelligent sensors, and then using improved fuzzy and Markow chain three-ratio method, David triangle method, cubic graphic method and other algorithms. The comprehensive fault diagnosis and status evaluation of distribution transformers have achieved good results, mainly in the following aspects.

1) Improved accuracy. The monitoring system uses intelligent sensors to collect a variety of information affecting the condition of the equipment, and integrates a variety of factors for fault diagnosis. Compared with the traditional transformer fault diagnosis method, the monitoring system has a greater improvement, especially for the critical condition of information processing effect is better.

2) Good maintainability. The system independently conducts self-diagnosis and evaluation status for each device. When a device fails or there is a hidden danger in its health status, it will give a corresponding alarm. The operator can arrange maintenance strategies according to the severity of the failure. In addition, each algorithm module of the equipment can run independently. For the algorithm program that needs to be improved and maintained, it is not necessary to improve the entire system. Only a single sub-function needs to be modified without affecting other sub-functions.

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![System composition](image-url)
6. Conclusion
In order to improve distribution equipment reliability and emergency repair response speed, this paper introduces the idea of multi-agents and designs a monitoring system for power distribution equipment based on condition multi-agents.

1) By introducing a multi-agent hierarchical structure, the coordination ability and scalability of the system are enhanced.

2) Based on the design of multi-agents, the edge processing unit autonomy, scalability and strong on-site diagnosis capabilities are increased.

3) The diagnosis results of the monitoring system are divided into different levels, and it is more intelligent to help maintainers to arrange maintenance strategies according to the level of failure.

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