Int. J. Metrol. Qual. Eng. 14, 5 (2023)

https://doi.org/10.1051/ijmqe/2023005

International Journal of
Metrology and Quality Engineering

Available online at:
www.metrology-journal.org

Research article

Open Access

Information model of power distribution IoT terminal for high-rise building electrical fire monitoring

Tianhai Peng[1], Fan Yang[2], Lei Su[2], Lingyan Sun[3,*], and Yu Chen[3]

[1] State Grid Hubei Eletric Power Co. Ltd, Wuhan 430077, PR China
[2] State Grid Hubei Electric Power Research Institute, Wuhan 430077, PR China
[3] College of Electrical and Electronic Engineering, Shandong University of Technology, Zibo 255000, PR China

Received: 21 June 2022 / Accepted: 14 April 2023

Abstract. Fires caused by electrical reasons such as short circuits and leakage in low-voltage distribution network lines account for a relatively large proportion of the high-rise building fires. Building an electrical fire monitoring system for high-rise buildings based on the Internet of Things (IoTs) technology can monitor electrical circuits in real-time and reduce electrical fires. Aiming at the interconnection and intercommunication of the information exchange of the IoT terminals in the electrical fire monitoring system of high-rise buildings, this paper firstly analyzes the functional communication requirements of the electrical fire monitoring system of high-rise buildings, and combined with the requirements of functional communication, the information model required for electrical quantity collection and non-electricity collection functions is studied based on IEC 61850, which is conducive to the fusion and application of low-voltage distribution network monitoring data and existing distribution automation system data. At the same time, the location information logical node is established by supplementing, which realizes the determination of the spatial position of the terminal and the sensor, the location of the fire source can be determined by analyzing and calculating according to the spatial location information and the spatiotemporal sequence of the detection information. Finally, the information modeling of different types of monitoring terminal equipment is carried out and the configuration suggestion based on SCL language is proposed. By realizing the integration of low-voltage terminal unit (LTU) into the system and the configuration of LTU, the standard system of IEC 61850 can be actually operated. A monitoring terminal based on the proposed information model has been developed and applied to a building in Wuhan.

Keywords: High-rise building / electrical fire / power distribution IoT terminal / IEC 61850 / information model

1 Introduction

In recent years, there have been frequent fires in high-rise buildings, and fires caused by electrical causes account for a relatively large proportion of the total number. According to data from the Fire and Rescue Department Ministry of Emergency Management of China, there were 85,000 fires caused by electrical causes in 2020, accounting for 33.6% of the total. In electrical fires, 68.9% were caused by circuit problems such as short circuits, overload, and poor contact, electrical equipment problems caused 26.2%, and other electrical causes caused 4.9%. Electrical factor is one of the important causes of high-rise building fires. Monitoring power lines and electrical equipment in high-rise buildings can detect electrical fire risks early and reduce the number of fires caused by electrical causes.

The power lines of high-rise buildings are mainly the medium-voltage 10 kV and low-voltage 380 V of the distribution network, which are at the end of the power supply line and lack monitoring and management. In order to solve the problem of monitoring low-voltage distribution networks, the Internet of Things technology based on advanced sensing and communication has been widely researched and applied in low-voltage distribution networks [1]. High-rise building electrical fire monitoring systems relying on low-voltage power distribution Internet of Things technology can be established. For the monitoring of electrical fires in buildings, currently, the pre-judgment of fire risks is realized mainly through data collection of electrical fire risk characteristics such as the temperature of monitoring equipment and the environment and the leakage current of low-voltage distribution lines [2]. Najmurrokhman and Kusnandar [3] collects temperature and smoke sensor data in the XBee transmitter module, and processes the data

* Corresponding author: 591824299@qq.com

through the Cayenne IoT platform to issue a fire alarm. Bal and Tusher [4] proposes an "Advanced Fire Alarm" system equipped with a "Message Queue Telemetry Transport (MQTT)" agent on the network panel in order to ensure safety and security. The above research uses the Internet of Things communication technology and the Internet of Things protocol to upload monitoring data such as temperature, smoke, and leakage to the monitoring master station to monitor electrical fires. High-rise building electrical fire monitoring systems need to monitor various electrical quantities and various non-electric quantities, such as temperature and smoke, which still uses a private custom data format at the communication data model level. It involves a variety of sensing terminals and monitoring terminals. When establishing a monitoring system, it is difficult to achieve information interconnection. In addition, the existing electrical fire monitoring system relies only on line leakage current detection and cannot provide early warning monitoring of electrical fires caused by line overloads and arc faults.

A unified communication information model is required for terminal equipment to achieve interconnection and intercommunication. The current information model standard for substation equipment in power systems is IEC 61850. The semantic expression is standardized at the equipment level in power systems and is widely used [5]. IEC 61850 has also been researched and applied in medium voltage distribution automation. Aguiar and Alencar [6] puts forward two new logical nodes, it is beneficial to the realization of distribution transformer monitoring model, Han and Xu [7] puts forward the information model of feeder terminal unit (FTU) and distribution transformer supervisory terminal unit (TTU) in intelligent power distribution terminal. Han and Xu [8] studies the logical node LN related to small current ground faults. Ling and Liu [9] extended the model of fault location, isolation and non-fault section recovery. Guise and Cleveland [10] introduce DER to achieve semantic level interoperability based on IEC 61850-7-420. Chen and Sun [11] proposed a feeder topology logical node that satisfies the application of distributed feeder automation. IEC 61850 information model in low-voltage distribution terminals is beneficial to the data integration application of low-voltage distribution networks and existing distribution automation systems. The application of IEC 61850 in low-voltage distribution network needs to be explored further.

In the substation automation system, the substation configuration description language SCL defined by IEC 61850-6 can be used to realize the configuration of IEDs. The low-voltage distribution monitoring terminal can also use IEC 61850 SCL can describe the communication services and logical functions that LTU itself can achieve, and realize the self-description of LTU. Only the integration of LTU to the system and the configuration of LTU can be realized so that the standard system of IEC 61850 can be operated practically. Low-voltage distribution monitoring terminals require different configuration methods to meet the demand because of the different batches installed and because different terminals are subject to factors such as cost or intelligence. The IEC 61850 90-6 part [12] released by IEC TC57 in 2018 specifies the data model, communication mapping and engineering configuration of IEC 61850 for distribution automation systems, but it is mainly for distribution medium-voltage lines. Most information models required for low-voltage power distribution terminals have been unified in IEC 61850.

For the monitoring terminal of the electrical fire monitoring system of high-rise buildings, this paper analyzes the characteristics of the communication requirements of the electrical fire monitoring system and its functions based on IEC 61850 and studies the information model required for functions such as electrical quantity collection and non-electricity collection based on IEC 61850 to realize the interconnection of monitoring terminal devices. The location information logical nodes are supplemented to realize the judgment of fire types and the traceability of fire starting points. And the information modeling of different kinds of monitoring terminal devices and the configuration suggestions according to the needs of different terminals were made, and the demonstration application was carried out in a park building in Wuhan.

2 Functional requirements for electrical fire monitoring in high-rise buildings

The high-rise building electrical fire monitoring system based on the Internet of Things technology mainly completes the monitoring and control of the electrical quantity on the line and the non-electricity of the environmental monitoring. The system architecture is shown in Figure 1, where low-voltage power distribution IoT terminals (LTUs), temperature sensors, and smoke sensors are installed on the low-voltage side of the distribution transformer, the line, and the user side. The LTU communicates directly with the edge computing gateway. The temperature sensor and the smoke sensor communicate wirelessly with the wireless concentrator. The edge computing gateway and wireless concentrator upload data to the cloud master station platform. Based on the monitoring information, the cloud master station performs electrical fire risk warning and fire point location after a fire. Maintenance personnel or users access the cloud platform through the desktop or mobile applications to monitor the entire system.

The basic function of a high-rise building electrical fire monitoring system is the Supervisory Control And Data Acquisition (SCADA) function of electrical quantity and non-electricity. In addition, fault detection and early warning functions for low-voltage lines are the system's essential functions. It mainly include short-circuit fault, series arc, and parallel arc, residual current, and line overload detections.

Short-circuit failure is an important cause of electrical fires. When a short-circuit fault occurs, the line fault current becomes more than ten times the rated current. If the protection fails to trip in time, it will quickly overheat and cause a fire. The existing short-circuit fault protection mainly adopts the principle of inverse time overcurrent. When a short-circuit fault occurs, once the circuit breaker fails to operate, the backup circuit breaker protection will delay the fault tripping, causing a fire.

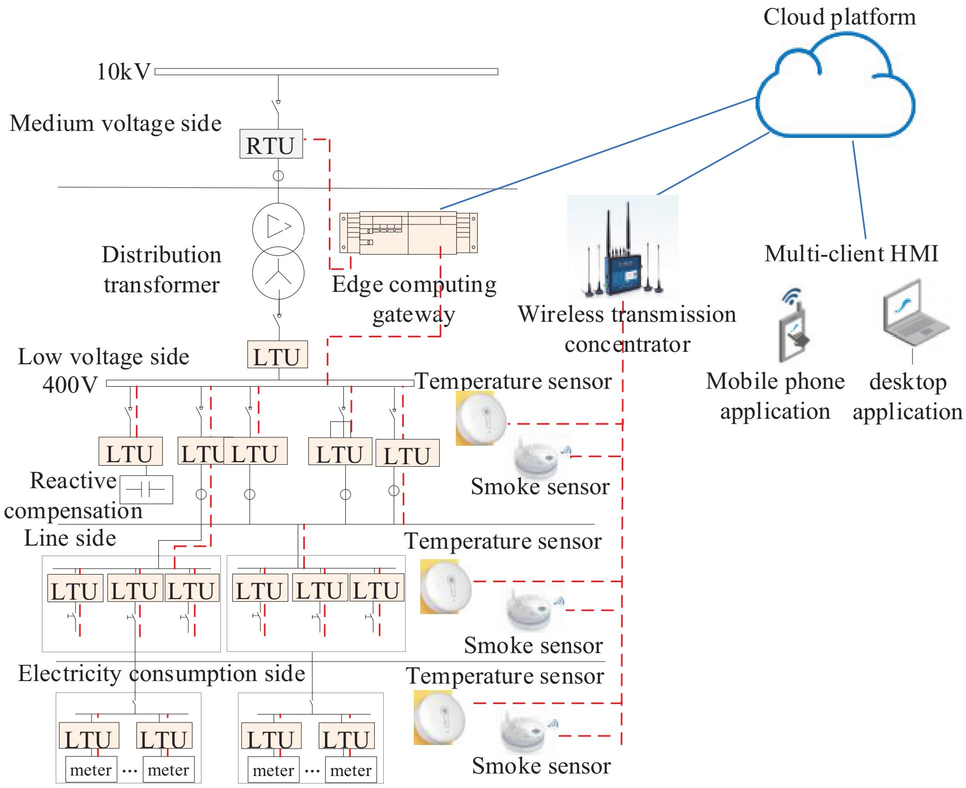

Fig. 1. High-rise building electrical fire monitoring system.

Arc faults are also a major form of failure on low-voltage distribution lines. Arc faults are divided into parallel arcs and series arcs, where series arcs are a series discharge phenomenon caused by damaged conductors, loose connection terminals, or poor contact in low-voltage distribution lines, Parallel arcs are arc faults that occur between the wires. When a parallel arc occurs, its arc energy is enough for combustibles and insulating materials to catch fire in a short period. Compared with series arcs, parallel arcs are hazardous and are more likely to cause fires. They should be detected quickly and accurately. Due to the influence of fault transition resistance, load type, and load current, the difficulty of the existing arc protection is the selection of the current protection threshold. The electrical fire monitoring system for high-rise buildings based on multi-point LTU provides the possibility for communication-based arc protection schemes.

Line overload is also one of the causes of electrical fires. Long-term overload will increase the insulation's temperature in the electrical circuit, line joints, and equipment wiring terminals, resulting in overheating the line or equipment, and may even cause a fire.

The above-mentioned detection function for electrical fault requires data modeling of the detected voltage, current fault characteristic, start-up setting, coordinated time delay setting, start-up conditions, and fault indications to meet the functional interaction requirements. In addition, communication-based fault detection methods need to get the information regarding the line topology, so topology configuration needs to be considered when modeling.

The location of the fire point is also a critical matter when fire occurs. In addition to LTUs, there are many non-electricity sensors in the building, such as temperature sensors, smoke sensors. The monitoring data from the sensors and the alarm information during a fire can be used to determine the point of fire and find the cause of the fire. The location of the fire is generally based on various types of electrical fire characteristic physical quantities, which are used to determine the time and space location information of the fire source and electrical faults. The information coincidence in the temporal logical and spatial location is used to distinguish between electrical and non-electrical fires. The spatial position information of each terminal and sensor is crucial in the location of the fire point.

The high-rise building electrical fire monitoring system based on the Internet of Things technology can monitor the electrical operating status of the line, collect non-electric sensor information, deal with faults, and reduce or avoid electrical fires. In order to achieve the functions mentioned above, LTUs and various non-electricity sensors of different manufacturers need to be interconnected, especially, the communication semantics need to be consistent.

3 Terminal function information model

The low-voltage power distribution IoT terminal (LTU), temperature sensor, and smoke sensor are equipment that complete the monitoring and control of various electrical

Table 1. Description of logical node.

Logical node name	Description
MMXU	Measurement
MSQI	Sequence and imbalance
MMTR	Metering Phase
XSWI	Circuit switch
XCBR	Circuit breaker
ZCAP	Capacitor bank
MMET	Meteorological information
STMP	Temperature supervision
TTMP	Temperature sensor
MENV	Environmental information
SSMK	Smoking conditions supervision
KFIM	Fire situation management
PTUV	Undervoltage
PTOV	Overvoltage
PTUC	Undercurrent
PTOC	Time overcurrent
PIOC	Instantaneous overcurrent
PVOC	Voltage controlled time overcurrent
SVPI	Voltage presence indicator
SCPI	Current Presence Indication
SFPI	Fault Passage Indication
RDRE	Disturbance recorder function
RADR	Disturbance recorder channel analogue

Note, the following unexplained LN descriptions can be found in this table.

and non-electrical quantities. Each device communicates with an edge computing gateway or a wireless transmission concentrator through a communication channel. When modeling information based on the IEC 61850 standard method for LTU, temperature sensors and smoke sensors, it is necessary to first analyze their functions and determine their corresponding functional logic nodes LN according to the corresponding functions.

LTU, temperature sensor, and smoke sensor mainly complete electrical quantity collection, non-electricity collection, line topology identification, fault detection, and processing.

3.1 SCADA model

The logical node LN modeled by IEC 61850 can meet the needs of electrical quantity collection [13]. The telemetering function realizes the measurement of electrical quantities such as voltage, current, active power, and reactive power. Remote signaling realizes the measurement state of switches, circuit breakers, etc. The main logical nodes required include MMXU, MSQI, MMTR, XCBR, XSWI, ZCAP.

For high-rise building electrical fire monitoring systems, temperature, smoke, and other environmental monitoring information are important. The meteorological information logical node MMET is defined in IEC 61850 7-4, which can characterize the environment's temperature, humidity, rain, snow, wind, and other information. For the indoor temperature detection of the building, the MMET logical node is unsuitable. For temperature information, the STMP logical node is also defined in IEC 61850 7-4 [14], which includes the temperature measurement value STMP.Tmp, and can also set the temperature alarm value STMP.TmpAlmSpt and provide an alarm signal output STMP.Alm. Most temperature sensors have only a temperature detection function and no alarm function. Therefore, the temperature sensor logical node TTMP is separately defined in IEC 61850 7-4, which mainly includes the detected temperature attribute TTMP.TmpSv and the sampling frequency fixed value TTMP.SmpRte. For temperature sensors that have only a temperature detection function, TTMP can be used. For temperature sensors with alarm function, STMP is recommended.

Smoke detection and fire alarms are also the focus of electrical fire monitoring systems for high-rise buildings. For smoke and flood information, MENV logical nodes are set in IEC 61850 7-4, which define the measured values of CO_2, CO, NO_x, SO_x, and other gases, so that smoke or flood warnings can be made according to those values. In order to meet the needs of more application scenarios, a new logical node SSMK and a KFIM logical node were newly built for smoke detection and fire alarm in IEC 61850-90-6 subsequently formulated by IEC TC 57. The original MENV logical node is no longer recommended.

The main attributes of the smoke condition supervision logical node SSMK are shown in Table 2. When the detected smoke level exceeds the alarm threshold SSMK. SmokAls, the SSMK.SmokAlm alarm is output.

3.2 Line topology information model

Applications such as low-voltage distribution line fault handling and economic operation analysis need to get information regarding the real-time line topology. The real-time topology of the low-voltage distribution network is determined by its static topology combined with the switching status of the switches on the line. For the low-voltage power distribution terminal LTU, local topology can be configured, and the edge computing gateway obtains the local topology and combines the switch status to realize topology recognition.

For the description of topological relationships, the IEC 61850 hierarchical model can be built using the substation configuration language SCL defined by IEC 61850-6, and described in the model configuration file CID using a unified and standardized format. IEC 61850-6 Ed2.1 has newly added Process and Line elements, which can be used to describe the topology of the distribution network [15]. Line elements represent the distribution network's main lines and branch lines, and substation describes the stations. When the network contains both Substation and Line, the Process container needs to be used in the upper layer to represent the local network. For the topology of the low-voltage power distribution network, a Process container is needed to describe each outgoing line, and substation describes the power distribution room and switchboard.

Table 2. Data objects of SSMK.

SSMK			
Data object name	Common data class	Explanation	PresCond nds/ds
Status information			
SmokAlm	SPS	If true, the smoke level has gone over the threshold SmokAls, and the alarm is considered as active.	M / F
EEHealth	ENS (HealthKind)	inherited from: EquipmentInterfaceLN	O / F
Settings			
SmokAls	ASG	Smoke level alarm threshold (measured as the density of particles, i.e., the number of particles per volume unit)	O / F
BlkRef	ORG	inherited from: FunctionLN	Omulti / F
...			

Table 3. Data object of SSLI.

Data object name	Common data class	Explanation	M/O
description			
EEName	DPL	inherited from:EquipmentInterfaceLN	M
NamPlt	LPL	inherited from:DomainLN	O
Settings			
X	ASG	longitude or x-axis value	M
Y	ASG	latitude or y-axis value	M
Z	ASG	height or z-axis value	M
SpcMod	ENG	location information representation method (SpcModeKind)	M
SpcID	DPL	Space ID	O

3.3 Fault detection and processing information model

For low-voltage distribution lines, residual current protection is mainly used to protect electricity safety. Because of the difficulty in setting the starting threshold value, sometimes the existing residual current protection will not operate. Developing the low-voltage power distribution IoT terminal LTU can further improve the protection scheme and monitor the low-voltage arc phenomenon in real-time, reducing fire hazards.

In IEC 61850 7-4, various protection methods are modeled accordingly, such as the logical nodes PTUV, PTOV, PTUC, PTOC, PIOC, PVOC related to fault detection, but there is no fault indication logical node for distribution lines. In IEC 61850 90-6, besides the fault reporting logical node (SFRP), logical nodes SVPI, SCPI, and SFPI related to fault indication are newly created. In addition, some protection methods require transient data recording, which can be recorded in Comtrade format, and then managed by RDRE and RADR logical nodes. The existing fault detection-related logical nodes can meet the application of the low voltage fault detection method.

4 Terminal location information modeling

After an electrical fire in a high-rise building occurs, to locate the fire's location, it is necessary to perform calculations based on the spatial position of the terminal and the sensor and the time-space sequence of the detection information. Among them, the spatial position data of the terminal and the sensor is vital. There is no logical node in the existing IEC 61850 to realize this function and a new logical node needs to be built.

4.1 Object attribute analysis

In order to accurately describe the spatial position of an object, a coordinate system is usually established to describe the object's position using mathematical methods. The position can be defined according to the geodetic reference system, such as the geodetic latitude and longitude coordinates, or it can be defined as the relative positional relationship between the objects, such as spatial adjacency, inclusion. A building is typical three-dimensional space, and object positions in the space can be expressed according to

Table 4. Enumeration of SpcModeKind.

Mode	Value	Explanation
RelativeCoord	1	Relative coordinate method, whose reference point is defined by the user
LatLongMode	2	Longitude and latitude method
Other	3	

three-dimensional coordinates (x, y, z) as well as the reference point.

For all kinds of low-voltage power distribution IoT monitoring terminals and sensing terminals for electrical fire monitoring in high-rise buildings, the ignition point location algorithm needs to analyze the location of the fire source according to the installation location of the temperature sensor and the smoke sensor and the time series of detection information. Therefore, the location information in this system should be as accurate as possible.

For LTU, temperature sensor, and smoke sensor, only the spatial location information of its installation point is needed while its spatial topology properties, such as adjacency are not.

For the ignition point location algorithm of the master station, it not only needs to get the spatial location information of each LTU and sensor installation point but also the topological relationship of the interior space of the high-rise building, the relationship between the LTU and the sensor contained in each space, and the spatial relationship between the LTU and the sensor. Summarized as follows, the spatial information required by the system includes:
– LTU and sensor installation location information.
– Topological relationship of interior space of high-rise buildings.
– The relationship between LTU, sensor, and each space.
– Adjacent relationship between LTUs and sensors.

The engineering configuration has two processing methods for the LTU and sensor installation location information. The first method is to configure it in the LTU, and the LTU saves the installation location information; the second method is to save and maintain it in the master station and associate it through the device identification ID. From an object-oriented point of view, the LTU should keep its complete information, so we choose the first method.

The above (2), (3) and (4) are the information required by the master station and do not need to interact through communication. It should be the local information of the master station, and no communication modeling is required.

4.2 Information modeling

For the position in the three-dimensional space of the building, it can be expressed by three-dimensional coordinates (x, y, z). The specific value depends on the coordinate system and reference point.

The coordinate system can be a geographic coordinate system or relative coordinates within a building. The geographic coordinate system is the latitude and longitude coordinate system. For the spatial position inside the building, longitude, latitude and height representation require high measurement accuracy, and it is not easy to apply in practice. However, considering other possible applications, it can be considered when modeling.

The geographic coordinate representation method is based on the representation method with the earth's center as a reference point. For high-rise buildings, we are more concerned with the relationship within points and between points and spaces in the interior space of the building. For example, taking a certain point on a high-rise building as a reference point to establish three-dimensional Cartesian coordinates can also describe the relationship within points and between the points and spaces in the interior space of the building.

The geographic and relative coordinate methods require three-dimensional coordinate values, namely x, y, and z. For the geographic coordinate method, x is the longitude, y is the latitude, and z is the height (in meters), all of which can be expressed using real numbers. For the relative coordinate method, x, y, and z are the values on the coordinate axis of the relative reference point (in meters).

Additionally, an attribute needs to be modeled to indicate which coordinate system to use. For the spatial position using the relative coordinate method, the device can also choose to configure the identification of the space or subspace.

For the spatial location information model, it mainly supports the management of the equipment installation location information by the monitoring system, so the logical node group should select the S group, that is, the first letter of the logical node is S. The attributes of the newly created logical node space location information SSLI are as follows.

The location information representation method attribute SpcMod is an enumeration value of SpcModeKind type, and the SpcModeKind mode is shown in the following table.

5 Terminal modeling and configuration

5.1 Terminal modeling

Each logical node implements the information model of each specific function, and the terminal unit is the realization carrier of different functions, so it is also necessary to model the terminal unit. The intelligent electronic equipment (IED) that needs to be modeled in the low-voltage power distribution IoT mainly includes low-voltage power distribution terminals LTU, non-intelligent sensing terminals, and gateways (edge computing nodes).

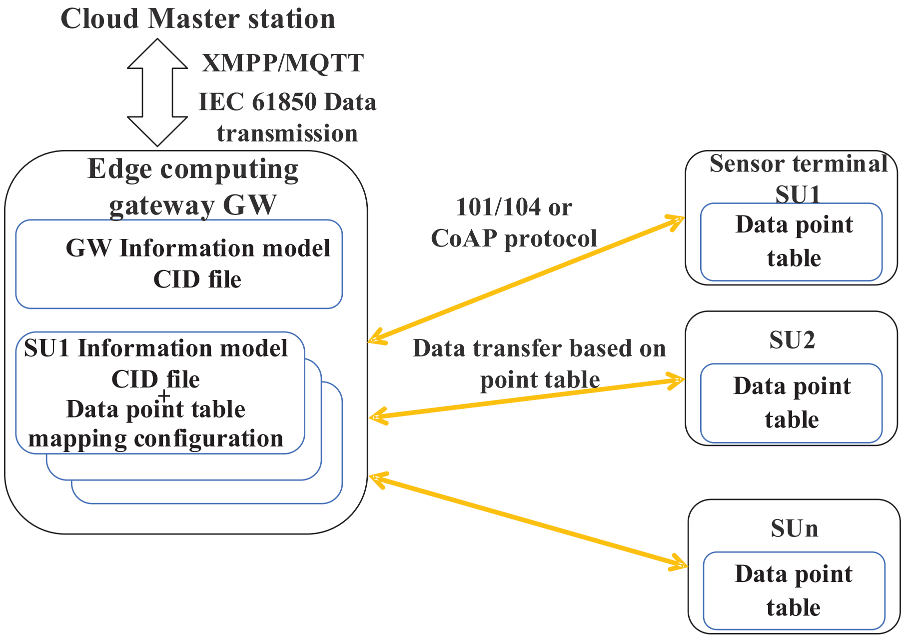

Fig. 2. Non-intelligent sensor model configuration.

For IED device modeling, IEC 61850 specifies that the IED is modeled as a device object. This object is a container that contains server objects, which should contain at least one logical device object. It can be divided by function for logical device LD modeling, and this method can also be followed for low-voltage power distribution IoT terminal LTU.

5.2 Terminal information model configuration

In the substation automation system, the configuration of the IED is pre-planned by the substation designer, that is to say, the intelligent devices are known and can be integrated and configured uniformly.

In this mode, automatic recognition and plug-and-play of smart devices are not necessary functions [16]. However, for the low-voltage power distribution IoT system, the number of LTUs is large, the geographical space is scattered, distributed control, and real-time line topology changes are much more complicated than the substation automation system [17].

For communication gateways or master stations, LTUs are connected in multiple batches with installation, and no centralized configuration is performed before access. For this reason, the engineering configuration of LTUs is particularly important.

Low-voltage power distribution IoT terminal equipment includes LTU, temperature sensor, smoke sensor, etc. These terminal units are generally cost-constrained and have less computing power. In addition, most temperature, humidity, and smoke sensors have low intelligence and limited resources and often do not have the conditions to apply the IEC 61850 information model directly. Therefore, for low-voltage power distribution IoT terminals, different information model configuration methods are required to adapt to their needs.

The LTU generally has certain computing power and resources and can be directly modeled by the information model described by the SCL of IEC 61850, but the complexity should be minimized when modeling the terminal. There are many LTUs, but they can be divided into several different types according to the number of analog quantities, switch quantities, and their functions in a specific project. Before installing the project, configure the corresponding ICD files according to category. After installation, it is instantiated to form a CID file.

For non-intelligent sensors, such as temperature, humidity, and smoke sensors, some installed sensors close to the LTU can collect and upload the sensing data through the LTU, and the information model can be modeled in the LTU's measurement LD. However, most of the temperature, humidity, and smoke sensors have a certain distance from the LTU installation point, and they need to be modeled as IEDs alone. In this case, a proxy-based IED modeling method can be used. As shown in Figure 2, the edge computing gateway GW communicates with the sensor using the communication protocol supported by the sensor. At the same time, as the agent of other sensors, the GW converts the sensor information into IEC 61850 data objects to standardize the information of non-smart sensors. The non-intelligent sensor communicates with the GW according to the private data format, and the associated information between its data and the IEC 61850 data object needs to be configured in the GW. If the calculation and communication resources of the LTU are sufficient, the specific project can also consider the LTU as the proxy of the sensing terminal near its installation point, and its implementation method is similar to the GW proxy method.

The number of IEDs in the substation automation system is limited, and the project time is concentrated, so the IEC61850 engineering configuration method in the substation is static configuration based on model files. The IED

Fig. 3. Main interface of high-rise building electrical fire monitoring system.

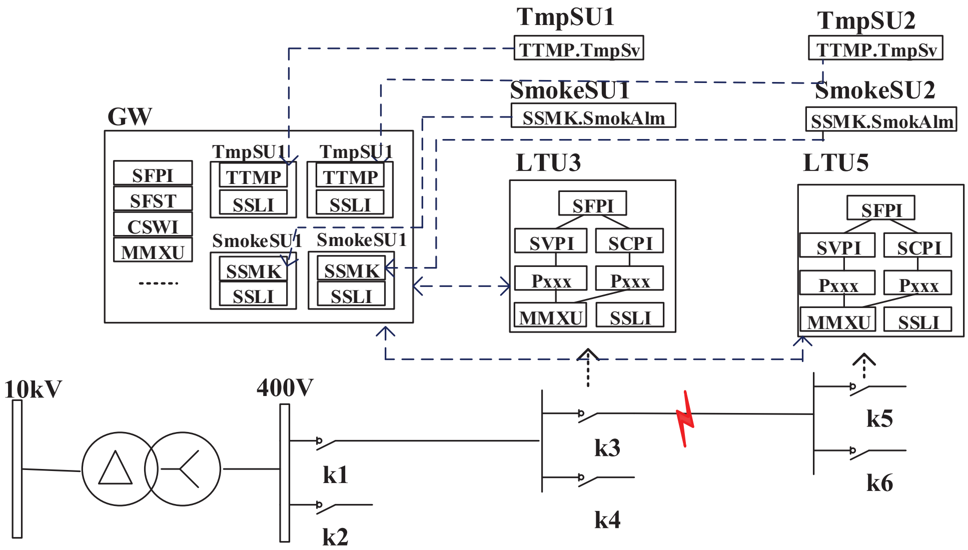

Fig. 4. Information model configuration for the project.

capability description file ICD and the system specification description file SSD are aggregated and configured, then decomposed into an IED configuration file CID and downloaded to a specific IED, a top-to-bottom configuration method.

The number of IEDs in the low-voltage power distribution IoT is huge, and the installation is often carried out in batches and stages. There are many different installation and maintenance scenarios. Therefore, its IEC61850 engineering configuration should support top-to-bottom configuration and bottom-to-top configuration. The configuration method from bottom to top refers to the configuration method in which the IED equipment is automatically registered, and the model information is uploaded to the GW or the master station after the IED equipment is installed and configured on-site.

6 Field application

In this paper, to solve the problems of lack of monitoring for low-voltage distribution lines in high-rise buildings and poor electrical fire monitoring capabilities, based on the IEC 61850 information model and terminal information model configuration, a high-rise building electrical fire monitoring system was developed and applied in a high-rise building in Wuhan. The system realizes the monitoring of the building's power distribution room, power distribution panel, low-voltage lines, smoke, and temperature sensors and reduces the occurrence of electrical fires through the monitoring of low-voltage electrical faults. The main interface of the high-rise building electrical fire monitoring system is shown in Figure 3.

The information model configuration of the arc fault detection based on multi-point measurement information is shown in Figure 4. The LTU is installed at the branch line switch, and the temperature and smoke sensors are installed in the room simultaneously. The LTU is configured with P-type protection logical nodes in IEC 61850, and the specific configuration depends on the detection algorithm used. The edge computing gateway can use the reported information of LTU3 and LTU5 to locate the fault location. Temperature and smoke sensors are modeled in the edge computing gateway, such as temperature sensors TmpSU1 and TmpSU2, and smoke sensors SmokeSU1 and SmokeSU2 in Figure 4. Such

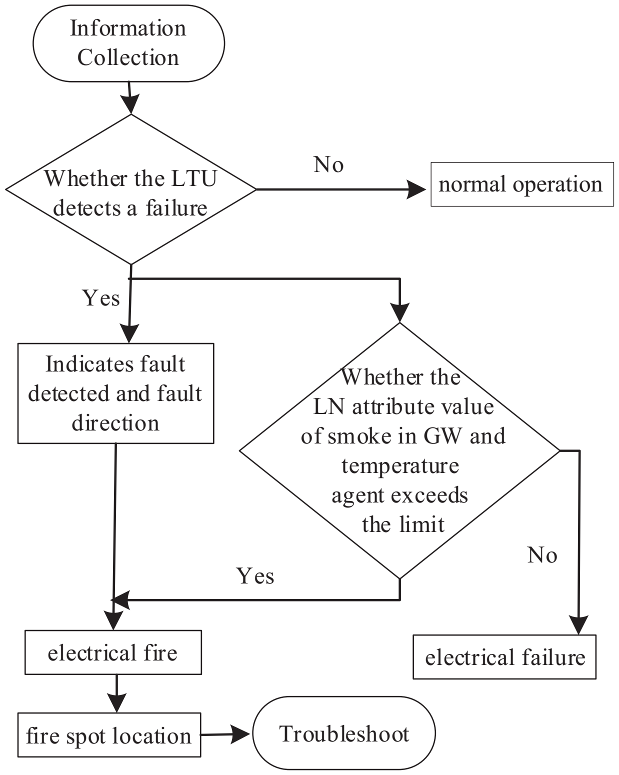

Fig. 5. Electrical Fire Detection Flowchart.

sensor communication is generally a private protocol, after the edge computing gateway interacts with it, it associates the reported data with the information model in the edge computing gateway. For example, the temperature data of the temperature sensor TmpSU1 is assigned to the TTMP. TmpSv of TmpSU1 in the edge computing gateway.

The LTU, temperature sensor, and smoke sensor are all configured with the spatial location information logical node SSLI. When locating the ignition point after a fire occurs, it can be judged by a corresponding algorithm according to the time-series changes of electrical quantity, temperature, smoke, and spatial relationship.

As shown in Figure 4, when a fault occurs, the fault indication information detected by the protection logical nodes in LTU3 and LTU5 at points K3 and K5 is collected to SFPI through SCPI (generated by detecting current) or SVPI (generated by detecting voltage), and SFPI.FltInd is used to indicate whether a fault is detected. If the fault direction is detected, use SFPI.Str Data object indication. Assuming that the sensors at K3 and K5 are far from the LTU, they communicate with the wireless concentrator through wireless communication, the wireless concentrator communicates with the GW, the TTMP.TmpSv attribute in the virtual agent TmpSU1 in the edge computing gateway and the TTMP.TmpSv in the virtual agent TmpSU2 If the attributes reach the predetermined temperature value (can be preset), and the smoke agents SmokeSU1 and SmokeSU2 both send out smoke alarms, it is judged that an electrical fire has occurred. Through the spatial location information of the sensors at K3 and K5 of the SSLI logical node in the GW, To determine the location of the fault, the flow chart is shown in Figure 5.

7 Conclusion

Building an electrical fire monitoring system for high-rise buildings based on the Internet of Things technology can monitor electrical circuits in real-time and reduce electrical fires. There are many low-voltage power distribution monitoring terminals and various sensors in high-rise buildings' electrical fire monitoring systems, and it is necessary to solve the interconnection problem. Using IEC 61850 in the low-voltage distribution monitoring terminal to solve the communication semantics and service consistency is beneficial to the data fusion application of the low-voltage distribution network and the medium-voltage distribution automation system.

This paper analyzes the information models required for electrical quantity collection and non-electricity collection functions based on IEC 61850 for the monitoring terminal of the electrical fire monitoring system in high-rise buildings. Different kinds of monitoring terminal equipment are modeled, and their configuration suggestions are put forward. The monitoring terminal developed in this paper has been demonstrated in a building in Wuhan, China.

Acknowledgments. The authors would like to express their gratitude to EditSprings (https://www.editsprings.com/) for the expert linguistic services provided.

Funding Information

The work was supported by a grant from Science and technology project of Hubei Electric Power Co., LTD (grant no. 52153220001V).

References

1. J. Lü, W. Luan, R. Liu et al., Architecture of distribution internet of things based on widespread sensing & software defined technology, Power Syst. Technol. (2018)
2. L. Zhu, W. Yao, Y. Xiong, Design and experiment of smart fire electric power monitoring system based on the cyber-physical model, in *2021 IEEE 2nd International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA)*, 2021, pp. 542–547
3. A. Najmurrokhman, Kusnandar, U. Komarudin, A. Daelami, R. Arisandy, Development of internet-of-things based building monitoring system for supporting the disaster mitigation in the city, in *2019 4th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE)*, 2019, pp. 179–183
4. D. Bal, M.M.I. Tusher, M. Rahman, M.S.R. Saymon, WSN based advanced emergency fire alarm system using MQTT centric star topology, in *2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD)*, 2021, pp. 156–160
5. B. Xu, Y. Xue, T. Li et al., A wide area measurement and control system for smart distribution grids and its protection and control applications, Autom. Electric Power Syst. **36**, 2–9 (2012)

6. G. de Franca Aguiar, H. de Alencar, J. Baesso, V. Wilhelm, B. Cassia, H. Wilhelm, Implementation new logical nodes – BIOP and ELTR based on IEC 61850, IEEE Latin Am. Trans. **18**, 1390–1397 (2020)
7. G.Z. Han, B.Y. Xu, Modeling of intelligent distribution terminal according to IEC 61850, Electr. Power Autom. Equip. **31**, 104–107 (2011)
8. G.Z. Han, B.Y. Xu, Information modeling for line selection device and section location single-phase earthing fault in non-effective earthed power system based on IEC 61850, Autom. Electr. Power Syst. **35**, 57–60 (2011)
9. W.S. Ling, D. Liu, Y.M. Lu et al., IEC61850 model expansion toward distributed fault localization, isolation, and supply restoration, IEEE Trans. Power Del. **29**, 977–984 (2014)
10. L. Guise, F. Cleveland, A. Apostolov et al., Facilitating the operation and integration of DER and microgrids using the IEC 61850-7-420 standard data models, especially for meeting IEEE 1547 and EN 50549 grid code requirements, in *CIRED 2021 - The 26th International Conference and Exhibition on Electricity Distribution* (2021), pp. 1807–1811
11. Y. Chen, L. Sun, Z. Wang et al., Distribution network topology identification based on IEC 61850 logical nodes, Sci. Program. **2021**, 1–8 (2021)
12. International Electrotechnical Commission, Part 90-6 (TR): use of IEC 61850 for distribution automation systems, in *IEC 61850, Communication Networks and Systems for Power Utility Automation* (IEC, Geneva, Switzerland, 2017)
13. H. Wu, X. Teng, C. Zhou et al., Implementation method of plug and play for station area equipment based on IEC 61850, Southern Power Syst. Technol. **15**, 72–78 (2021)
14. International Electrotechnical Commission, Part 7-4: Basic communication structure—Compatible logical node classes and data object classes, in *IEC 61850, Communication Networks and Systems for Power Utility Automation, ed.2.0* (IEC, Geneva, Switzerland, 2010)
15. International Electrotechnical Commission, Part 6: Configuration description language for communication in electrical substations related to IEDs, in *IEC 61850, Communication Networks and Systems for Power Utility Automation, ed. 2.0* (IEC: Geneva, Switzerland, 2010)
16. J. Ying, Y.M. Cai, M.X. Liu et al., Adaptive access method of low voltage intelligent terminal for distribution internet of thing, Autom. Electric Power Syst. **44**, 22–27 (2020)
17. C. Xu, Y. Lei, Y. Zou, A method of low voltage topology identification, in *2020 IEEE Conference on Telecommunications, Optics and Computer Science (TOCS)* (2020), pp. 318–323

Cite this article as: Tianhai Peng, Fan Yang, Lei Su, Lingyan Sun, Yu Chen, Information model of power distribution IoT terminal for high-rise building electrical fire monitoring, Int. J. Metrol. Qual. Eng. **14**, 5 (2023)