Data Standard Interface of Distribution Network Equipment Inspection Automation System

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Abstract. For the current inspection of distribution network equipment based on manual input detection, there are problems such as correctness and low efficiency. This paper proposes a set of standard data interfaces to improve the automation level of inspection equipment. Due to the diversity of charged detection instruments, the detection information entry has been stuck in manual paper records, collecting picture information, time-consuming and labor-intensive in the later manual finishing, spending a lot of time in forming test reports, unable to combine historical detect data, similar test data and other information on the production management system in time for accurate device status analysis. This study firstly develops a standardization model for the inspection information of distribution equipment, realizes the online acquisition inspection plan, and seamlessly interacts with the production management system. Secondly, for the detection data access, a data security access protocol is established, wireless communication and mobile applications are integrated, and automated transmission of live detection data is realized. Finally, for the problem of inconsistent detection data acquisition format, a standardized model of live detection data is defined, and a standardized integrated interface is built based on the intelligent inspection application of the distribution network equipment, so that the mobile application for detecting data is automatically entered. The patrol inspection automation system based on the data standard model interface has been put into the field application and achieved good results.

1. Introduction
In recent years, with the rapid development of China's economy, the electricity consumption of residents and enterprises has increased rapidly, and the pressure of distribution network operation has surged, resulting in a multi-fold growth of distribution network operation equipment. For the growing scale of distribution network equipment, how to ensure the normal and orderly operation of distribution network equipment has become a difficult and key point.
Ensuring the normal use of electricity by residents involves the operation and maintenance management of distribution network equipment, including the daily inspection of distribution equipment. The inspection management of the distribution network equipment includes arranging the inspection route, testing the distribution network equipment through the detection equipment, and inputting and analyzing the detection data.

For today's huge number of distribution network devices, manually entering the detection data is not enough, and the current input method will affect the accuracy of the detection data, resulting in deviations between the detection results of the distribution network equipment and the reality. The current inspection of distribution network equipment mainly adopts data manual input method, and there are the following main defects:

Low accuracy: Artificially associated network distribution equipment and test data, manual recording of test data, there are cases of manual record errors, which may lead to misjudgment of the operation of the distribution network equipment.

Low efficiency: Manual recording is a huge workload because the inspection record is a multi-system operation. The inspection process takes a long time and the inspection efficiency is low, which affects the evaluation of the operation of the distribution network equipment.

In response to the above problems, this paper proposes a set of standard data interfaces for the inspection automation system of distribution network equipment.

2. Data standardization model scheme

2.1. Distribution network equipment inspection information standardization model

At present, the inspection work of most teams or power supply stations still stays in the custom inspection plan in the production management system, and then the inspection plan of the day is sorted into a form and printed into a paper document and then taken to the job site according to the order of the paper document test equipment. The inspection is carried out, and the inspection data is recorded by the inspection instrument, and the collected inspection data is recorded, and then returned to the office for sorting and input into the production management system, and the detection report is manually generated. The on-site inspection instrument only has the function of detecting data collection, and it is unable to obtain the test plan and the status information of the test equipment in real time. The test data collected on site is not recorded in the production system in time. The on-site inspection instrument data acquisition system has become an independent information island compared to the production management system, and cannot share real-time information with the production management system.

Power resources are represented by classes, objects and attributes, and relationships between them. The unified modeling language UML (unified modeling language) is used to define the common classes, attributes, and relationships between objects in the power industry. The data of the distribution network equipment of the unified data structure provides an important guarantee for the standardization of the inspection information of the distribution network equipment. Therefore, the inspection information of the distribution network equipment is standardized, and the unified and standardized data interface service is adopted, which can realize the closed-loop management of the whole process of the inspection of the distribution network equipment more efficiently. Based on the IEC 61968 standard, the patrol data standardization method of the distribution network equipment defines the patrol information data structure of the distribution network equipment according to the object-oriented thinking, and realizes the standardization of the equipment inspection information.

Based on the object-oriented design idea, the inspection management of distribution network equipment is divided into detection cycle, inspection plan and detection result. The relationship between the three is shown in Figure 1. The implementation of the standardized model is mainly described by classes and objects. Classes are static, and their existence, semantics, and relationships are defined before the program is executed. Objects are dynamic and can be dynamically created and deleted while the program is executing. According to the detection object, distribution network
equipment can be divided into two categories: line equipment type and station equipment type. According to the type of detection, it is divided into infrared temperature measurement, load measurement, partial discharge measurement and grounding resistance measurement.

![Figure 1. Distribution network equipment inspection management object map](image)

2.2. Test instrument detection data access protocol

Although there are various kinds of live detection instruments on the market, manufacturers and models are different. The same detection type of live detection instruments may support different communication methods. For example, wireless communication technologies such as Bluetooth and WiFi can support the transmission of information such as pictures or voices, but there is no unified detection data access method, and data security access protocols are not available, and these wireless communications cannot be organically integrated with mobile applications. In turn, the implementation of automated transmission of charged detection data is restricted.

Currently, the live detection instruments used by the team generally supports Bluetooth or WiFi. Due to the requirement of transmission data and data complexity for the detection data, WiFi network communication is selected for transmission of detection data. Based on the analysis of WiFi and WiFi-SD card technology, standardize the detection data access method, design the mobile terminal detection data acquisition function, perform wireless communication data frame analysis according to the data communication frame definition, and Instant messaging obtains detection data, instead of traditional paper manual operation manual recording, directly transfers the images collected by the charged detection instrument to the mobile terminal through the shared hotspot. The cumbersome steps of transferring out through the removable storage medium are avoided, and the automatic transmission of the collected detection data is realized.

In order to realize the data transmission based on the WiFi end-to-end between the detection instrument and the mobile application end, the detection instrument needs to support the wifi function,
and the wifi is the AP mode, and the data of the detection terminal is received and uploaded by the mobile application. For different types of live detection projects, a unified communication protocol needs to be defined to ensure secure access to data. Define the general conventions, data frame format, detection type, control word definition and format, data structure and transmission rules for the communication between the live detection instrument and the intelligent inspection application. According to the data communication process, the detection instruments all adopt passive communication mode, the intelligent inspection application actively calls data, the IP network communication uses UDP protocol, UDP does not require maintaining a connection, and UDP does not have the overhead caused by the receiver's approval to receive the data packet. Can be used for short applications and control messages, and based on a packet connected to a packet, UDP requires less network bandwidth than TCP. The data packet adopts the data frame mode, and defines a start code, a detection type, a control word, a data field length, a data field, and a check code for the data frame. As shown in Table 1 and Table 2, the data frame detection type is defined.

Table 1. Transmission data frame structure

| Start code | Detection type | Control word | Data length | Data field | Check code | Terminator |
|------------|----------------|--------------|-------------|------------|------------|------------|
| 1 byte     | 1 byte         | 1 byte       | 2 bytes     | lengthen   | 2 bytes    | 1 byte     |

Table 2. Detection type definition

| Detection type | Meaning | Description |
|----------------|---------|-------------|
| 01H            | Noise measurement | Distribution |
| 02H            | Infrared thermal imaging detection | Distribution transformers, circuit breakers, CT, PT, isolating switches, combined electrical appliances, lightning arresters, reactors, capacitors, switchgear, etc. |
| 03H            | Ultrasound partial discharge detection | Distribution transformer, switch cabinet, cable |
| 04H            | Tentative state voltage detection | Distribution transformer, switch cabinet, cable |
| 05H            | Relative capacitance ratio | Capacitor |
| 06H            | Cable ground loop detection | Cable |
| 07H            | UV detection | Porcelain column circuit breaker, isolation switch |

After the detection instrument receives the contact information actively uploaded by the mobile application, the original command returns immediately. The mobile application sends the contact information every time. If the detection instrument has no return information, it will be sent every 10 seconds. If there is no response for 3 consecutive times, it will not be sent.

In addition to the transmission of the on-site detection data for the WiFi communication technology, the picture voice collected during the detection process can also be transmitted in real time through the shared hotspot through the wireless WiFi-SD card. Some infrared thermal imagers and PD instruments support wireless WiFi-SD cards. After inspecting the mobile application for device identification, the inspector enters the detection data collection function, and collects the temperature data collected by the temperature measurement device through the auxiliary input interface.

2.3. Standardized data model for live detection

Although a variety of charged detection instruments have appeared on the market, many have been able to achieve more accurate detection results, and some charged detection instruments can even support a variety of detection items, however, due to the diversity of the charging detection instruments, the detection data acquisition format is inconsistent, the detection information input has
been stuck in the manual paper record, the picture information is collected, the time and effort are spent on the manual finishing, and it takes a lot of time to form the test report. It is impossible to combine the historical detection data and the similar detection data on the production management system to perform accurate equipment state analysis in time. What is needed now is to develop a standardized model of charged detection data, and build a standardized integrated interface based on the intelligent inspection application of the distribution network equipment to realize automatic transmission of test data.

Based on the standardization system of the inspection equipment of the distribution network equipment, the corresponding relationship between the type of the detected equipment and the detection item is compiled, and the corresponding detection data template is compiled according to the corresponding relationship, and a unified detection data standardization model is formulated. Taking infrared thermal imaging detection and ultrasonic partial discharge detection as an example, the detection data template was developed. In accordance with the State Grid Corporation's network operation and maintenance management regulations (State Grid (Transportation Inspection / 4) 306-2014) and State Grid Corporation's network equipment status evaluation guidelines (Q/GDW645-2011), combined with infrared temperature measuring instruments and local discharge detection instrument characteristics, unified classification of distribution network equipment, is divided into: pole transformer, overhead other equipment (column switch, high voltage knife gate, drop fuse, lightning arrester, etc.), station transformer, cable connector (terminal head, the middle joint), the switchgear and the corresponding cable feed out a total of 5 categories of equipment, and develop the standardized data model of the above two types of live detection.

2.3.1. Infrared thermal imaging detection. The infrared temperature measuring device mainly measures the temperature information of the target device, and records the infrared temperature measurement picture. The infrared temperature measuring equipment mainly supports the transformer on the line equipment pole, the circuit breaker on the pole, the load switch on the pole, the circuit breaker on the pole, the line arrester, the cable and the transformer inside the station. Because the temperature measurement equipment manufacturers are different, the collection information is different, and the temperature measurement data of different equipment are standardized according to the production management system and the infrared temperature measurement specification requirements. For infrared detection and diagnosis methods, refer to DL/T664-2008 "Infrared Diagnostic Application Specifications for Live Equipment". The infrared spectrum should be comparable to three-phase or similar equipment. Formulate the infrared temperature standardization model, the transformer on the pole, the overhead line, the cable infrared measurement, and the transformer temperature detection data model in the station. The data model of the infrared temperature measurement on the pole transformer is shown in Table 3.
Table 3. Infrared temperature measurement data model of transformer on pole

| Test data standard model | Infrared imaging detection |
|-------------------------|-----------------------------|
| Test items              | Test data                   | Equipment type | Rod transformer |
| Test items              | Equipment type             | Is it necessary | Normal range of data | Abnormal range |
| Device name             | Character string           | Yes            | -                    | Associate test equipment key information |
| Instrument name         | Character string           | Yes            | -                    | |
| Instrument manufacturer | Character string           | Yes            | -                    | |
| Equipment manufacturer  | Character string           | No             | -                    | |
| Equipment model         | Character string           | No             | -                    | |
| Ambient temperature     | Digital                     | Yes            | ℃ (-10℃)~55℃         | More than 55℃, less than -10 ℃ |
| High pressure A phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| High pressure B phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| High pressure C-phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| Low pressure A phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| Low pressure B phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| Low pressure C-phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| Low pressure zero phase joint temperature | Digital | No            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| Maximum temperature of equipment | Digital | Yes            | ℃ (-10℃)~75℃         | More than 75℃, less than -10 ℃ |
| Conclusion              | Character string           | Yes            | -                    | Normal / attention / abnormal / serious |
| Remarks                 | Character string           | Yes            | -                    | |
| Infrared imaging map    | Image                      | -              | -                    | Not less than 3 sheets |

2.3.2. Partial discharge detection. When partial discharge occurs, a transient voltage will be generated on the reduced metal surface. This ground voltage will propagate along all directions of the metal surface, and the determination and localization of partial discharge of the power device can be realized by detecting the ground voltage. A dynamic detection map is generated when the discharge data of the equipment unit is collected. At present, the partial discharge detection equipment of the distribution network equipment is mainly the switch cabinet, cable and transformer in the test station. The standardization model of the local discharge detection data of the switchgear temporary ground state voltage, switch cabinet and cable is specified, as shown in Table 4 and Table 5.
Table 4. Switching cabinet temporary ground state voltage detection data model

| Test items                      | Transient ground voltage detection | Switchgear                  |
|---------------------------------|------------------------------------|-----------------------------|
| **Test data**                   | **Type of data**                    | **Is it necessary**          |
| Device name                     | Character string                   | Yes                         |
| Station name                    | Character string                   | Yes                         |
| Instrument name                 | Character string                   | Yes                         |
| Instrument manufacturer         | Character string                   | Yes                         |
| Equipment manufacturer          | Character string                   | No                          |
| Equipment model                 | Character string                   | No                          |
| Measuring part                  | Character string                   | No                          |
| Ambient temperature             | Digital                            | Yes                         |
| Humidity                        | Digital                            | Yes                         |
| Atmospheric background noise    | Digital                            | Yes                         |
| Metal object background noise   | Digital                            | Yes                         |
| Front upper                     | Digital                            | No                          |
| In front of the middle          | Digital                            | No                          |
| Below the front                 | Digital                            | No                          |
| Side of the top                 | Digital                            | No                          |
| Middle of side                  | Digital                            | No                          |
| Under of side                   | Digital                            | No                          |
| Back and upper                  | Digital                            | No                          |
| In the middle of the back       | Digital                            | No                          |
| The lower part of the back      | Digital                            | No                          |
| Conclusion                      | Character string                   | Yes                         |
| Remarks                         | Character string                   | Yes                         |
| Abnormal picture                | Image                              | -                           |

- Normal / attention / abnormal / serious

| **Unit**                        | **Normal range of data**           | **Abnormal range**          |
|---------------------------------|------------------------------------|-----------------------------|
|                                |                                    | (-10°C)~55°C                |
|                                |                                    | More than 55°C, less than -10°C |
|                                |                                    | 0%~85%                      |
|                                |                                    | More than 85%, less than 0%  |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
|                                |                                    | 0 dBmV ~60 dBmV             |
|                                |                                    | More than 60 dBmV, less than 0 dBmV |
### Table 5. Switchboard/cable ultrasonic partial discharge data model

| Test data                  | Type of data | Is it necessary | Unit | Normal range of data                                      | Abnormal range                                                                 |
|---------------------------|--------------|----------------|------|----------------------------------------------------------|-------------------------------------------------------------------------------|
| Device name               | Character string | Yes            | -    | Associate test equipment key information                | Associated power station key letter                                           |
| Station name              | Character string | Yes            | -    | Associated power station key letter                     |                                                                               |
| Instrument name           | Character string | Yes            | -    |                                                           |                                                                               |
| Instrument manufacturer   | Character string | Yes            | -    |                                                           |                                                                               |
| Equipment manufacturer    | Character string | No             | -    |                                                           |                                                                               |
| Equipment model           | Character string | No             | -    |                                                           |                                                                               |
| Measuring part            | Character string | No             | -    |                                                           |                                                                               |
| Ambient temperature       | Digital       | Yes            | °C   | (-10°C)–75°C                                            | More than 55°C, less than -10°C                                              |
| Humidity                  | Digital       | Yes            | %    | 0%–85%                                                   | More than 85%, less than 0%                                                  |
| Background noise value    | Digital       | Yes            | dBmV | 0 dBmV ~60 dBmV                                         | More than 60 dBmV, less than 0 dBmV                                          |
| Detected value            | Digital       | Yes            | dBmV | 0 dBmV ~61 dBmV                                         | More than 60 dBmV, less than 1 dBmV                                          |
| Conclusion                | Character string | Yes            | -    | Normal / attention / abnormal / serious                 |                                                                               |
| Remarks                   | Character string | Yes            | -    |                                                           |                                                                               |
| Infrared imaging map      | Image         | -              | -    |                                                           |                                                                               |

Based on the standardized model of the live detection, the auxiliary input interface of the standardized intelligent inspection application detection data is designed. Regardless of the detection method of the live detection instrument, as long as it meets the requirements of access data, data type and data specification in the corresponding live detection data model, it can break the traditional manual input-post-finishing traditional mode and improve the speed of detection data collection, save half the time of manual entry.

### 3. Conclusion
For the current inspection of distribution network equipment based on manual input detection, there are problems such as correctness and low efficiency. This paper proposes a set of standard data interfaces, and based on this interface, designs and implements the automatic inspection system for...
distribution network equipment. This paper implements standardized model design for typical infrared thermal imaging and partial discharge detection types. Later, it will build a standardized model for more types of charged detection, and expand the application range of broadband electrical detection information automatic transmission technology, for example, noise detection, ultraviolet detection, relative capacity ratio detection and so on.

The applicability of the standard interface model in this paper is verified by field application. The system based on the standard interface can obtain the inspection plan and test equipment data of the production management system in real time, and receive the test acquisition data of the test instrument in real time. The system outputs the inspection plan and test equipment data obtained from the production management system through the intelligent inspection software of the distribution network equipment, that is, the mobile application side of the mobile phone, and the data collected by the inspection test instrument is recorded into the production management system in real time to realize real-time data sharing and interaction between the intelligent inspection application and the production management system.

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