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Discrimination and Prediction System for Overheat Faults of Substation Equipment

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Abstract. The traditional discriminating of overheat faults of substation equipment by manual calculation is cumbersome, and it fails to deepen the application of the temperature measurement data. Based on the theoretical system of ubiquitous power Internet of things, the paper designed a discrimination and prediction system for overheat faults of substation equipment which were composed of four modules as intelligent data acquisition and analysis terminal, mobile phone client APP, substation equipment inspection management system and the analysis of big data platform by combining cloud, pipe, edge, field and terminal architecture systems. The discrimination and prediction system for overheat faults of substation equipment integrated multi-technology such as IoT communication and identification, cloud computing and storage, big data processing and analysis etc. The analysis results of the system can provide decision support for the intelligent management of substation equipment.

Keywords. Substation equipment, overheat faults discrimination, overheat faults prediction, multi-technology integration

1. Introduction

Infrared temperature measurement technology is an online monitoring method with the advantages of no disintegration, no contact, no power failure, and non-destructive. It is widely used in power generation, transmission, substation and distribution.

As a key node of the power grid, the reliability of power grid can significantly improve if it can timely and effectively detect and evaluate the operation status of the substation equipment. The normally defects of substations equipment are overheat defaults, including voltage-induced type and current-induced type. References [1-2] analyzed the cases of the abnormal overheat defaults of CVT and put forward some suggestions for CVT's daily maintenance. Reference [3] summarized the reasons of overheat defaults of 35kV dry type reactor's ground block of two 500kV substations, and pointed out that it was necessary to measure the temperature of the ground block at the same time when infrared temperature measurement was performed on the equipment ontology. Reference [4] analyzed the overheat defaults case of the current transformer, and proposed that the infrared temperature measurement of the protective equipment and the terminal block should be strengthened. Reference [5] analyzed a lightning arrester breakdown case and it was suggested that the temperature difference between the upper and lower parts can be used as a reference for the discrimination of lightning arrester

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overheat defaults. The infrared monitoring system for substations based on the intelligent visual internet of things was proposed in Reference [6], the system can accurately and timeliness detect and locate the abnormal temperature areas of equipment, continuously monitor excessive temperature areas and provide fault warnings. The new intelligent inspection robot developed by Reference [7] can complete the daily maintenance work such as inspection and temperature measurement of substation equipment, and can greatly improve the carrying capacity of the grass-roots team.

2. Inadequacies of Traditional Infrared Temperature Measurement Methods

At present, the temperature measurement of substation equipment still mainly depends on manual work. The temperature of the substation equipment changes dynamically with the ambient temperature and the load during the daily operation. When the staff member qualitatively determines the abnormal overheat defaults of the equipment, it is necessary to quantify the defect manually, and then refer to *The Equipment Defect Standard Library of State Grid* to classify it [8]. This traditional overheat defaults discrimination process is cumbersome and the result may be subjective.

The traditional infrared thermometers cannot accurately obtain the on-site ambient temperature which can affect the accurate discrimination of substation equipment overheat defaults. On the other hand, the current application of the overheat defaults data of substation equipment is only used for equipment status analysis during the temperature measurement period. For the massive historical temperature measurement data, it is lack of deep information mining and utilization [9, 10]. Therefore, it is necessary to design a discrimination and prediction system for overheat defaults of substation equipment (hereinafter referred to as the DPS).

3. Development of the DPS

3.1. Overview of the DPS

According to the characteristics of overheat defaults of substation equipment and the concept of ubiquitous power internet of things, the DPS is composed of four modules as intelligent data acquisition and analysis terminal (perception layer), mobile phone client APP (network layer & application layer), substation equipment inspection management system and the analysis of big data platform (platform layer) by combining cloud, pipe, edge, field and terminal architecture systems.

The data flow and functions of the DPS are shown in Figure 1.

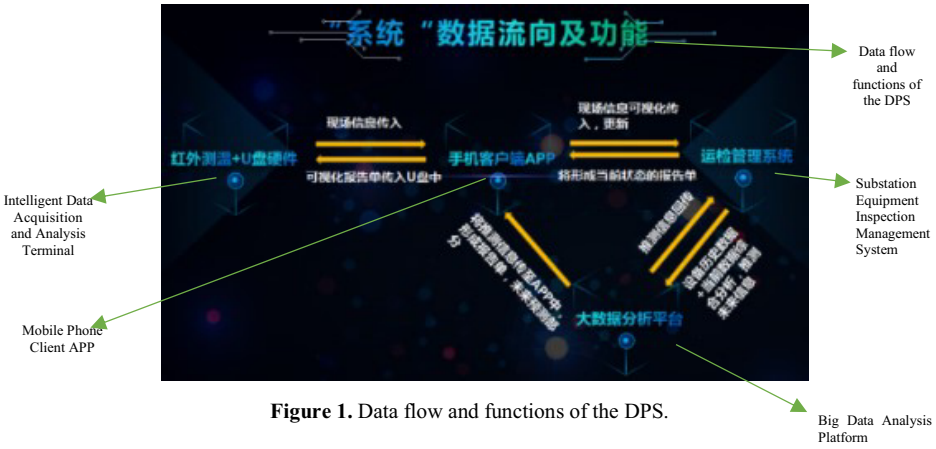

Figure 1. Data flow and functions of the DPS.

3.2. Intelligent Data Acquisition and Analysis Terminal

The intelligent data acquisition and analysis terminal has the functions of substation identification, interval identification, equipment type identification, automatic identification of temperature measurement hot spots and normal points. The infrared temperature measurement images and temperature measurement information can be transmitted to the mobile phone client APP through the terminal communication module, and it also can receive the equipment overheat defaults discrimination and prediction report from the mobile phone client APP. The functions of the intelligent data acquisition and analysis terminal are shown in Figure 2.

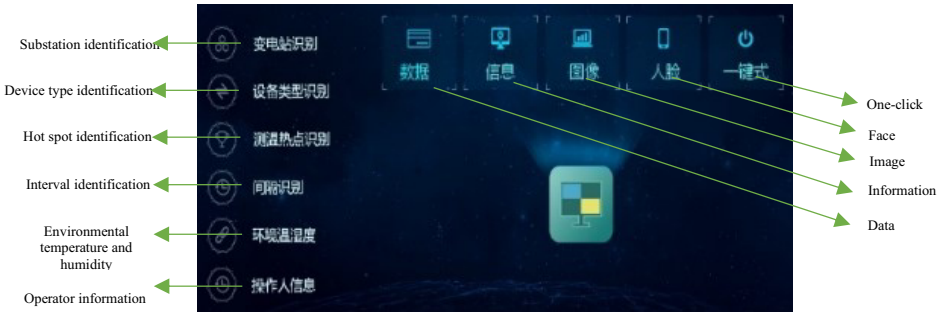

Figure 2. The functions intelligent data acquisition and analysis terminal.

3.3. Mobile Phone Client APP

The transmission method used by the mobile phone APP is the representation of the network layer and the application layer in the power IoT. It can automatically store and analyze the overheat defaults images and information received from the terminal to generate the current overheat defaults discrimination report and then transmit the temperature measurement data or images to the substation equipment inspection management system at the same time. Furthermore, the mobile phone APP can receive the prediction report from the analysis of big data platform. The mobile client APP interface is shown in Figure 3.

Figure 3. Schematic diagram of device heating defect discrimination interface in mobile phone client APP.

3.4. Substation Equipment Inspection Management System

This module is used to manage the information of regional substations, substation equipment and staff member in a unified manner. It can receive and store the terminal equipment thermal data, synchronize the substation equipment data with the mobile phone APP, provide data query and operation authority for different personnel. This module and the big data analysis platform described in the latter are the application of the platform layer in the power Internet of Things. It's based on the strong platform support that data conversion and instruction operations can be completed.

The interface diagram of the substation equipment inspection management system is shown in Figure 4.

Figure 4. Interface diagram of substation equipment operation and inspection management system.

3.5. Big Data Analysis Platform

The big data analysis platform is connected to the substation equipment inspection management system, it can provide storage capacity for massive temperature measurement data through big data storage technologies such as HDFS and HBase, and

show the real-time status of substation equipment through big data processing technologies such as Storm and large-screen data visualization. Combined the historical data of substation equipment with artificial intelligence algorithm to analyze and predict the status of the equipment, the big data analysis platform can comprehensively evaluate the use and replacement plan of the substation equipment. The schematic diagram of the big data analysis platform interface is shown in Figure 5.

Figure 5. Big data analysis platform interface schematic diagram.

3.6. Coordination of Each Module of the DPS

According to the description of the functions of the four modules of the system above, the core report sheet generated by the DPS consisted of two parts. One is the discrimination report of the current equipment heating defects. The other is the prediction report of the equipment overheat defaults in the future. And the four modules of the DPS designed in this paper also focus on how to generate these two reports. The schematic diagram of generating report form for DPS is shown in Figure 6.

Figure 6. Schematic diagram of generating report form for DPS.

4. Effectiveness and Advantages of the DPS

4.1. Effectiveness of the DPS

In this section, the paper shows a discrimination report generation process for the overheat defaults of the substation equipment. The example as follows.

In a 220kV substation, between the B-phase current transformer and the isolated switch at the line side of the interval named 220kV Shangshi-II Road 278, the lead wire clip's temperature measurement value at the CT side was 64.9℃, while the A-phase temperature measurement value was 43.9℃, and the C-phase temperature measurement value was 43.5℃, the ambient temperature was 30℃, the temperature measurement value of the CT lead wire clip in the adjacent normal operation interval was 36℃, and the current load of interval 278 was 248.3A.

Figure 7 showed the result of the traditional manual calculation and the result of the DPS designed in the paper. It can be seen that the report generated by the DPS was rich in information with readability and repeatability.

Figure 7. The test results of two different ways.

4.2. Advantages of the DPS

Compared with the traditional manual calculation, the DPS proposed in this paper has significant advantages as follows.

- Promptness

The data acquisition and analysis module of the system can automatically identify the information of the temperature measurement object, and synchronously transmit the information collected to the system for subsequent in-depth mining and utilization.

- Accuracy

The system can calculate the relative temperature difference and absolute temperature difference based on formulas of the industry standard to ensure accuracy.

- Universality

The mobile client APP has been developed in two versions of Android and IOS, and they have been promoted and applied on site.

- Timeliness

The DPS can generate the overheat defaults discrimination and prediction reports and send them to relevant departments or personnel remotely in time to accelerate the relevant processes promotion or arrangements for eliminating defects.

- Decision-making

The DPS can generate the overheat defaults discrimination and prediction report which can provide data and decision support for intelligent management of substation equipment.

5. Concluding Remarks

Compared with the traditional manual calculation, the DPS designed in this paper integrates the concept of ubiquitous power Internet of Things, the technology of communication and identification, the cloud computing and storage, the big data processing and analysis and so on. These technologies can quickly discriminate the current overheat defaults of substation equipment and speed up the process of eliminating defects. It also can provide data and decision support for the intelligent management of substation equipment. The DPS has broad development and application prospects in the future.

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