Intelligent Operation Inspection Technology Based on Panoramic Perception

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Abstract: The paper describes the intelligent operation inspection mode based on panoramic perception and its practical application in a substation. By upgrading substation to panoramic perception substation, we will focus on solving the problems of insufficient perception, insufficient data analysis, and insufficient data application in the current substation operation inspection practices, thereby increasing the management level of professional intelligent substation operation inspection through five aspects: equipment perception capabilities, status control capabilities, active early warning capabilities, precise maintenance capabilities, and management penetration capabilities.

Keywords: panoramic perception, intelligent operation inspection, edge computing, mobile operation, substation

1. Introduction

Traditional substation inspections require substation operation and maintenance personnel to patrol several substations one by one and collect data within his jurisdiction. The workload is heavy and the efficiency is low. Generally, operation and maintenance personnel can only patrol 2-3 substations per day, consuming a lot of time on journey. In recent years, with the development of various information collection sensors and remote data transmission technology, operation and maintenance personnel can remotely view the basic data and images of substations, which can greatly reduce their burden of arriving to the scene. With the development of computer technology, various data visualization methods have been continuously developed. It is necessary to use the current advanced visualization display methods to upgrade the substation monitoring system and increase the data utilization rate [1].

2. Current Status of Substation Operation Inspection

At present, there are still some problems to be solved in the development of intelligent operation inspection services for substations. There is insufficient information perception in the station, and information blind areas exist in the monitoring of mechanical characteristics of circuit breakers and isolating switch motions, as well as intelligent management and control of personnel violations, etc. The application of intelligent data analysis is insufficient. In the past, data analysis is often based on pure threshold analysis, which is relatively simple, and the data analysis of each device and system is relatively independent, lacking systematic comprehensive analysis. Also, on-site intelligent equipment fails to obviously improve the maintenance efficiency and effectiveness.

3. Panoramic Perception-Based Substation Construction Plan

In this case application, the substation is upgraded to a panoramic sensing substation, and the infrastructure in the station is fully upgraded. 11 sub-function modules are installed, including intelligent inspection, video +, and online monitoring to comprehensively collect information in the station. At the same time, the station-side system can exchange information with PMS, D5000, intelligent operation inspection management and control platform, big data evaluation and analysis system for transmission and transformation equipment, etc., thus obtaining real-time telemetry and telesignal data. Moreover, all information is pushed to municipal and provincial platforms to create an "Internet of Things Perception" with ubiquitous access to equipment and service interconnection. The panoramic perception substation improves the operation inspection management level of the substation mainly through the following five capabilities:

3.1. Data acquisition

In terms of hardware, the breadth and latitude of data acquisition are expanded by deploying robot inspection, video +, online monitoring; 11 types of sub-function modules are installed in the station, 39 types and 667 sensors are arranged to fully gather the personnel, equipment, and environmental information in the station [2].

In terms of software, the substation is modeled in a three-dimensional panorama in a 1:1 ratio, so that the collected environmental information such as temperature and humidity can be displayed in real time; the equipment is modeled using modular and unitized fine modeling methods. For instance, in modeling of the main transformer, it divides the main transformer into modules such as the main transformer body, on-load tap-changer,

and main transformer bushing. At the same time, the online monitoring, telemetry and telesignal signals are correspondingly associated with the unit modules. The operator only need click on the relevant module on the 3D model to dynamically view the panoramic information of the relevant module in real time. The three-dimensional module split is accurate to the maintenance unit. The displacement of each indicator on the switch cabinet or the protection screen, the service status of the protective pressure plate, and the information of each air chamber of the combined electrical appliance can be dynamically displayed and viewed on the three-dimensional model in real time.

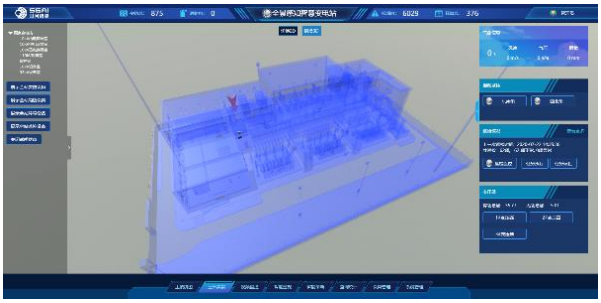

Figure 1: Panoramic 3D modeling

Figure 2: Three-dimensional model of switch cabinet

3.2. Status control

Through application of image recognition technology, it is possible to automatically identify and record whether personnel wear safety helmets, whether they use safety belts in climbing operations, and whether there are irrelevant personnel in lifting operations, thus implementing real-time control of on-site personnel's safety behaviors.

Through application of intelligent inspection and "video +" technology, one-key sequential control is possible, which fully replaces manual routine inspections and lights-out inspections. The overall inspection workload can be reduced by 86% and the operation workload can be reduced by 24%.

In special patrols and professional patrols, personalized custom patrol content is possible. For example: #2 main transformer is running under high load, which needs strengthened inspection and infrared temperature measurement. After the PMS system delegates special patrol tasks during the high load period, the station-side system can be remotely called to configure the patrol content and form a patrol plan. At the same time, the patrol robots, infrared and visible light cameras in the station corresponding to the plan will automatically complete the patrol and upload the patrol results. After storage of the patrol plan, if the station-side system detects next time that the #2 main transformer is under high load operation, it will automatically call the patrol plan to complete the intelligent inspection and implement the intelligent linkage between the station-side information perception and automatic inspection.

Figure 3: Remote special patrol

3.3. Active early warning

A video analysis server and a big data analysis server are added on the substation side to screen, process, and dig into the telemetry and telesignal signals and video signals collected by the system in real time, and finally generate warning signals that can be truly helpful for maintenance personnel, thus achieving edge computing. The generated early warnings mainly have two modes. One is direct early warning. When an abnormality is detected in the station, the alarm information is actively pushed. 73 new types of telesignal signals and 103 new alarm signals are added to the station. The other is comprehensive early warning. Using NLP and knowledge graphs to build an intelligent operation inspection expert database, it implements intelligent decision-making for operation inspection based on entity discovery and relationship extraction technology, graph data storage and knowledge reasoning technology [3]. To formulate appropriate data structures and algorithms, it need discover and extract the relationship between equipment failures and phenomena such as light, electricity, heat, vibration, etc., to form equipment state evaluation criteria. When a certain type of data abnormality is detected at the station, the relevant light, electricity, heat, and vibration signals can be automatically retrieved, so that early warning information is pushed based on the evaluation criteria after the equipment status is automatically reasoned and predicted.

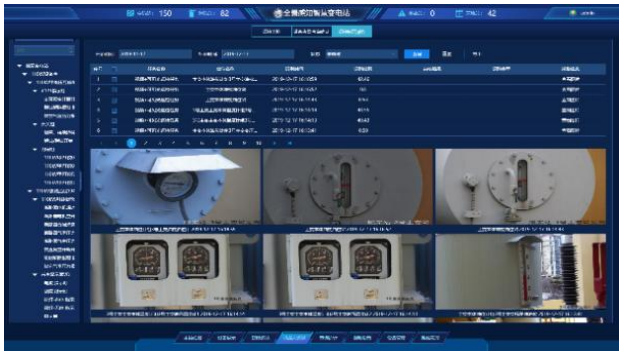

Figure 4: Artificial intelligence meter reading

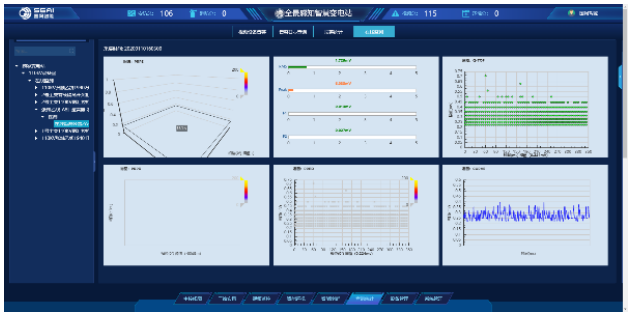

Figure 5: Real-time data analysis

3.4. Accurate maintenance

According to the early warning information of the substation, the equipment status evaluation is automatically performed to form the targeted maintenance strategy based on the "five regulations" of the substation. The 7 types of equipment have 46% coverage of independent maintenance strategy. The panoramic perception system provides evaluation based on the status of the five regulations, and performs regular operation status scanning of the primary equipment of the substation. If the system detects that a certain equipment status meets the equipment failure conditions in the five regulations, it will send the alarm together with the corresponding maintenance strategy to the person in charge of the substation [4]. After the maintenance tasks are assigned, the maintenance personnel can acquire maintenance strategy using the mobile terminal, conduct remote site surveys through the three-dimensional panoramic model, retrieve the real-time data of the substation, the real-time picture of the video system, and control the robot to conduct fixed-point inspections. Through the application of on-site mobile operation terminals, the automatic identification and entry of test results are possible, the maintenance quality is real-time and visually controllable, so that the efficiency of maintenance operations is improved.

3.5. Management penetration

Substation equipment has been covered and equipped with physical ID. Using physical ID as a tool and data as the starting point, it runs through the entire chain of life cycle management of equipment, PMS, ERP system, serial equipment procurement, operation and maintenance, overhaul, and decommissioning, thus realizing data penetration of "using one data to the end" [5]. By deepening the penetration of equipment status evaluation management, inspection management, maintenance management, and emergency repair management, it increases the workload of inspection operations, improves the maintenance efficiency, improves the intrinsic safety of the equipment, and extends the equipment service life, thereby increasing cost control over the entire life cycle of the equipment.

4. Typical Application Scenarios

Taking the 110kV circuit breaker closing coil unable to be electrically closed as an example, the whole process from the discovery of the problem to the problem solution is explained.

The station-side system learns from the D5000 system that the switch has a remote closing operation, and will automatically adjust the camera and robot to check the mechanical position and electrical indication of the switch, then record the online mechanical characteristics monitoring data, D5000 related signals of the switch. It will automatically analyze the above signals and generate an alarm "switch control loop failure, remote closing is impossible; coil failure is 90% possible", together with maintenance strategy "it is recommended to carry out Class D maintenance, check the control loop, and if necessary, carry out Class B maintenance to replace components", which will be pushed to the operation inspection personnel. At the same time, the problem is automatically entered into the PMS defect system.

After receiving the alarm information from the handheld mobile terminal or PC, the operation inspection personnel can remotely view various signals through the three-dimensional panoramic model, conduct manual review, and arrange personnel to issue work order in the PMS after error correction.

After the maintenance personnel obtains the work order, alarm information, and maintenance strategy through the mobile terminal, a standardized work card is automatically generated so that they can work according to the card, and use the mobile terminal to take pictures and record the test results. The test reports will be automatically generated based on the rest result through image recognition and uploaded to the PMS system.

5. Conclusion

Intelligent operation inspection of substation is an innovative and modern comprehensive inspection technology. By using this technology in power system substation equipment, it can effectively improve the comprehensive inspection efficiency of substation equipment to a certain extent. Moreover, it also represents the main trend of future power grid development. Therefore, relevant substation equipment maintenance personnel should actively use the intelligent substation operation inspection technology with a mentality of advancing with the times. Only in this way can we effectively promote the development of the power industry towards higher stability.

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