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Development and application of a substation work ticket inspection tool based on big data cloud platform



Abstract: - In the context of the digital transformation of the power grid, based on information data mining and information fusion technology, fully utilizing big data cloud platforms to develop and apply substation work ticket inspection tools, innovating application data scenarios in the deep implementation of safety production, solving the problems of traditional work ticket inspection content and process timeliness. Through the application of substation work ticket inspection models, it is fully verified that substation work ticket inspection tools improve inspection efficiency and quality, and play a positive role in reducing personal and equipment risks during on-site operations.

Keywords: Lean; Big data cloud platform; Security measures; Process management.

I. INTRODUCTION

A work permit is a written basis for maintenance personnel to carry out maintenance, regular inspection, installation, renovation, debugging, testing, and other work on the power production site, equipment, and system. It is a written safety agreement jointly held and enforced by both maintenance and operation personnel. It is an important organizational and technical measure to prevent personal and equipment accidents during the process of power equipment maintenance. The work permit system is the basic system for safe production in power enterprises, and is the core content of the power safety work regulations. It plays a very important role and significance in ensuring the safe operation of power grid equipment. In recent years, with the rapid development of power grid construction, the number of substations under its jurisdiction has been increasing year by year. [1] Unmanned, intelligent, and lean transformation are important directions for the production reform of the substation profession. Against the background of the transformation of the production organization mode of the substation profession and the optimization of human resource allocation, the number of on-site substation operation and maintenance personnel has been continuously decreasing. However, under the influence of factors such as the increase in equipment quantity, overdue operation, and power outage windows, the workload of on-site inspection is constantly increasing. In the process of equipment power outage maintenance, there is a high demand for on-site work tickets, which are tight in time, heavy in tasks, and numerous in quantity. Especially in the safety measures and instructions of work tickets, the standardization and correctness of safety measures affect personal and operational safety. Therefore, it is crucial to improve the efficiency of handling work tickets while ensuring safety standards. [2]

With the improvement of digitalization and informatization in power enterprises, a power grid information management platform has been established, which collects, applies, and processes information from various levels of the power system through the system, providing great convenience for on-site work ticket processing [3]. Currently, there is a lot of research and development on intelligent work ticket systems for work tickets in China. Reference [3] proposes an intelligent work ticket automatic auxiliary generation system based on functions such as screen cabinet position graphic display, graphic invoicing, automatic generation of dangerous point pre control tickets, automatic linking of pressure plate diagrams, and Excel interaction; On the basis of preprocessing the basic data of work tickets, reference [4] transforms and analyzes unstructured data, establishes corresponding models, identifies the work ticket information filled in by the work leader, returns the corresponding information of work ticket security measures, and realizes the application of intelligent work tickets; However, currently most work ticket systems are built independently, with low timeliness and reliability of data sources. Although there is a certain degree of error prevention verification function, the level of intelligence in the error prevention process is not high. The error prevention work mainly relies on manual review, which takes up a long time, has low efficiency, and cannot detect problems in the work ticket in real time, affecting the correct use of the work ticket. Therefore, improving the timeliness of work ticket data and enhancing the level of error prevention intelligence are currently urgent issues that need to be addressed.

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II. OVERVIEW OF BIG DATA CLOUD PLATFORMS

The big data cloud platform used in the power system is based on the collection system, with Hadoop distributed architecture as the main framework, and the HDFS distributed file storage system integrating massive power grid data. It has non real-time distributed processing capabilities and can handle TB/PB level data reasonably, realizing various types of data processing activities and various application applications. The computing components of the big data cloud platform include HAWQ++, HIVE, SPARK and other computing components, providing users with a powerful computing engine. Users can choose suitable components for development and use according to business needs. The architecture of the big data cloud platform mainly includes seven core functions: data source layer, collection layer, storage layer, computing layer, service layer, distribution layer, and application layer. The main function of the data source layer is to provide power data sources, mainly for various built and formed power grid information systems and monitoring systems. The main function of the collection layer is to collect various types of power data, which can be achieved through a unified cloud ETL tool. The main function of the storage layer is to store, integrate, and statistics data. The data collected by the data source layer is divided into thematic databases and basic databases, and the data is statistically and integrated according to business needs. The main function of the computing layer is to calculate and calculate data in the storage layer, which can achieve batch computing, streaming computing, and other methods. The service the layer is the support for algorithmic analysis of computational data and providing data tool services. Algorithm analysis includes algorithms for power grid enterprises, analysis algorithms, and mining algorithms. Data tool services include SQL development, self-service analysis, and other services. The development layer provides various interface services for data application development, including interface governance tools, SPTP files, and so on, The application layer is responsible for application development and scenario monitoring of data sources based on business requirements, mainly including operational monitoring of business data and decision analysis of business data. In summary, big data cloud platforms form powerful and fast support capabilities for front-end data application requirements in a componentized and service-oriented manner, achieving data requirements for various businesses and scenarios.

III. SUPERVISION AND MANAGEMENT REQUIREMENTS FOR WORK TICKETS

A. *Inspection requirements for work tickets*

As a written basis for ensuring the implementation of safety measures, work tickets are mainly used in professional fields such as substation operation, maintenance, relay protection, and testing. They have the characteristics of multiple application scenarios, wide range, and flexible use. [6] According to the requirements of on-site work content and safety measures, different types of work tickets are selected. The most common ones are the first type of work ticket at the factory, the second type of work ticket at the factory, the third type of work ticket at the factory, and the written assignment work ticket. If a complete or partial power outage is required for high-voltage equipment, the first type of work ticket from the factory station shall be used. High voltage equipment does not need to be powered off. For work on the shell of live equipment, with sufficient safety distance and no possibility of touching the conductor part of live equipment, the second type of work ticket from the factory station shall be used. No power outage is required for high-voltage equipment. Non electrical work carried out by external units in the substation that does not affect the power outage of operating equipment, such as civil engineering, greening, firefighting, lighting, five protections, video, temperature measurement, special patrol, etc., which do not affect the power outage of operating equipment, the third type of work ticket from the factory station shall be used. No power outage is required for high-voltage equipment. Non electrical work carried out by our unit in the substation that does not affect the power outage of operating equipment, such as civil engineering, greening.

The application of work tickets in various scenarios of substations is influenced by various factors such as job skill level, workload, work time, and work environment, which can easily result in unqualified or non-standard work tickets, posing great risks to on-site work safety and personal safety. In severe cases, it can lead to accidents. According to incomplete statistical analysis, common types, causes, and risks of work ticket errors can be classified into the following categories (Table 1).

Table 1. Types and Analysis of Work Ticket Errors

Error type	cause analysis	Risk consequences
Selecting the wrong work ticket	Not familiar with work ticket classification	Accidentally entering and touching live equipment
Planned homework time error	Unverified power outage application form	Non power outage violation operation Accidentally entering and touching live equipment
Work task location error	Filling in work ticket error Inadequate on-site investigation	Wrong device interval Accidentally entering live equipment
Security measures content error	Filling in work ticket error Inadequate on-site investigation	Wrong device interval Accidentally entering and touching live equipment
License content error	Filling in work ticket error Not familiar with licensed devices	Security disclosure error Accidentally entering and touching live equipment
Change content error	Filling in work ticket error Not familiar with the change content	Loss of supervision at work Change violation of homework
End content error	Filling in work ticket error Unfamiliarity with ending content	Safety measures not removed for power transmission Terminate illegal operations

Therefore, in order to improve the accuracy of the content of the work permit, the focus of the inspection of the substation work permit should be on the selection of the work permit, the time of the work permit, the location of the work task, safety measures, permit content, change content, and termination content.

B. Management requirements for work tickets

The management of work tickets mainly includes the timeliness management of work tickets and the process management of work tickets. The process of a work permit mainly includes: filling out, issuing, co signing, receiving, licensing, changing, terminating, etc. Each process flow corresponds to different personnel roles and responsibilities. A correct and standardized work permit must be effectively executed in every process link. During the work permit filling stage, it is easy to issue incomplete work permits, resulting in errors in the face and safety measures of the work permit. During the issuance and co signing stages of work permits, it is easy to miss the issuance and co signing, resulting in a lack of necessary review and control of the work permit. In the stage of receiving work tickets, it is easy to encounter receiving time errors, resulting in not meeting the requirements of the work plan time. During the work permit approval stage, it is easy to disclose incomplete permit content, resulting in on-site safety disclosure becoming mere formality. During the work permit change phase, it is easy to encounter the risk of personnel, work, and time being changed but not changed, leading to the risk of changing operations on site. During the termination stage of the work permit, it is easy to end the work before it is completed, resulting in the loss of control over on-site work termination. The timeliness management of work tickets mainly includes: timely delivery rate, timely receipt rate, and timely return rate of work tickets. According to the Electric Power Safety Work Regulations of China Southern Power Grid Co., Ltd., the first type of work ticket at the station should be delivered to the substation operation duty personnel for review and acceptance 12 hours before the planned start time or one day before 17:00. The second type of work ticket at the station only needs to be delivered to the operation personnel for permission before the start of work. Therefore, the timely delivery rate is a key link reflecting the efficiency of work ticket filling, issuance, and co signing circulation, and is an important indicator for the early review of work tickets and the advancement of safety control checkpoints. The timely acceptance rate is a key link in the necessity of auditing work, compliance with maintenance schedules, completeness of safety measures, and efficiency of circulation. It is an important indicator to ensure that work is carried out as planned. The timely rate of rollback is a key link in reviewing work tickets, correcting errors or issues, and re implementing circulation efficiency. It is an important indicator to improve the correctness and standardization of work tickets. Therefore, in order to improve the efficiency of work ticket processing, it is necessary to focus on the process management and timeliness management of work tickets.

IV. DESIGN AND DEVELOPMENT OF WORK TICKET INSPECTION TOOL

A. Design of Work Ticket Inspection Tool

By analyzing the requirements for work ticket inspection and management, the overall framework of the substation work ticket inspection tool based on the big data cloud platform should include four levels: data access layer, data fusion layer, data analysis layer, and data display layer, as shown in Figure 1. [7]

(1) Data access layer: The access data source is the current power information management system (power grid management platform), and the same object data source is a single system with different servers, mainly accessing the work ticket module data of the power grid management platform.

(2) Data fusion layer: Based on fuzzy mathematics theory and neural network models, the big dataset is classified and processed, effectively integrating the data of the work ticket module connected to the power grid management platform.

(3) Data analysis layer: Further analyze the results of data fusion, decompose them into various content modules and process modules based on work tickets, and construct an inspection model for search and logical conditions to verify the correctness of the content and the rationality of the process.

(4) Data Display Layer: Display the work ticket data results or key indicators analyzed by the platform in a scenario based manner, and provide data export support. Visualize the data through electronic spreadsheets, intelligent graphics, and dashboard functions, making it intuitive and three-dimensional.

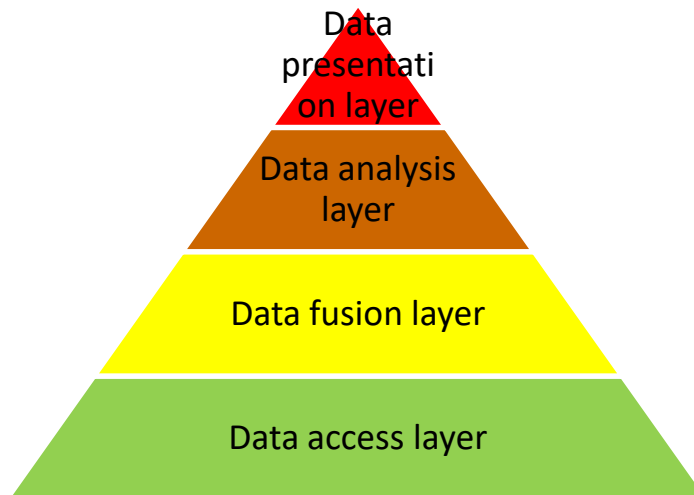


Figure 1. Hierarchy of Substation Work Ticket Inspection Tool Framework

In-line equations/expressions are embedded into the paragraphs of the text. For example, $E = mc^2$. In-line equations or expressions should not be numbered and should use the same/similar font and size as the main text.

B. Development of Work Ticket Inspection Tool

After the overall framework of the substation work ticket inspection tool based on the big data cloud platform is built, further construction of the tool hierarchy process is needed[8]. Firstly, set up a tool intermediate table to combine the data of the system work ticket with the inspection model. Setting up a tool intermediate table is convenient for work ticket application personnel to conduct data business analysis of work tickets. Work ticket data can be expressed in various forms such as numbers, text, symbols, etc. Extract from different system modules of work tickets according to professional focus, process and integrate the data to form structured data that can be recognized and calculated by computers.

In fact, it is to establish a work ticket inspection model. On the one hand, it is based on the content information of the work ticket module on the power grid management platform, to sort out the system of judgment criteria for work tickets that are not qualified or standardized, the implementation standards for work tickets, and the naming standards for safety, health, and environmental protection equipment. It deeply explores possible problems, establishes logical relationships among data in the system, uses SQL language to associate specific data fields with the data intermediate table of the business system, and finally establishes a work ticket inspection model based on logical rules. On the other hand, it is based on the process information of the work ticket module on the power grid management platform. According to the business guidance book and related

management systems of work ticket management, key information of the system process is screened, and rules for the work ticket process and timeliness are established. SQL language is used to associate specific process fields with the system's data intermediate table. Finally, a work ticket comparison plan is established based on the process and timeliness rules and included in the work ticket supervision model.

Finally, there is data validation and evaluation. By establishing a work ticket inspection tool model, abnormal data is screened out, and the data is further exported for analysis. The validity of data logic conditions and process rules is evaluated, and continuous optimization and improvement are carried out to ultimately achieve closed-loop control of the entire process. Therefore, it is possible to achieve a more rapid, accurate, and in-depth mining of a large amount of complex work ticket data information in the power grid management platform system, discover more problems and errors in work tickets, identify potential job safety risks, and provide more efficient and accurate correction suggestions.

C. Example of work ticket inspection tool

1) Work ticket content inspection model

(1) Work ticket tasks, work location verification analysis

Scope of application: The first, second, and third types of work tickets for factories and stations

Input content: Screen all work tasks and check if the content of the work location box meets the following conditions, as shown in Figure 2::

1. If there are "switches", "knife switches", "ground knives", "1M busbars", "2M busbars", "3M busbars", "5M busbars", "6M busbars", "TYD", "CT", "PT", "lightning arresters", "transformers", "transformers", "transformers", "transformers", "substations", they must include "500kV", "220kV", "110kV", "35kV", "10kV"

2. If there are "main transformers", "station transformers", and "grounding transformers", they must include "# 1", "# 2", "# 3", and "# 0"

3. If there are "screens" and "cabinets", they must include "P" and "T"

Output result: Suspected error labeling, and prompt for work task and work location errors[9]

(2) Verification analysis of circuit breakers (switches) that should be disconnected (double name or number)

Input content: Screen whether all corresponding box contents meet the conditions

Scope of application: (First type of work permit)

The first number includes: 8, 5, 3, 2, 1, F, C, for example: 5021, 801

The number of digits is generally 3 or 4.

Letter F+two digits, for example: F01

Scope of application: (Second and Third types of work tickets)

nothing

Output result: Suspected error labeling and prompt for circuit breaker (switch) error that should be disconnected

(3) Verification and analysis of filling in content for other safety measures precautions

Input content: Screen whether all corresponding box contents meet the conditions

Scope of application (first type of work permit, second type of work permit, third type of work permit)

If there is 500kV, there is a 5-meter field present

If there is 220kV, there is a 3-meter field present

If there is 110kV, there is a 1.5-meter field present

If there is 35kV, there is a 1-meter field present

If there is 10kV, there is a field of 0.7 meters

Output result: Suspected error labeling, and prompts for other safety precautions error

Seal Office

_____ The first type of work ticket at the factory station
number: _____

Work leader (guardian): Phone: Unit and team: Total number of work leaders and staff	Planned working hours	From ___ year ___ month ___ day ___ hour ___ minute to ___ year ___ month ___ day ___ hour ___ minute	
Whether to handle group work dispatch orders: <input type="checkbox"/> Yes, 0 in total; <input type="checkbox"/> No			
Work team members (excluding work leaders):			
Work tasks:			
Work location:			
work do want seek of security whole Measures Shi	Responsible person for implementing safety measures	The work permit holder is responsible for	The person in charge of the work is responsible for
	Circuit breaker (switch) that should be disconnected (double name or number)		
	Isolation switch (knife switch) that should be opened (double name or number)		
	The grounding switch that should be closed (double name or number), the installed grounding wire (installation location), and the installed insulation baffle		
	Relevant AC/DC power supplies (load switches, air switches, fuses, etc.), low-voltage and secondary circuits (connecting pieces, soft pressure plates, conversion switches, tail fibers, etc.) that should be switched on/off		
	Fences should be installed and signboards should be hung (location)		
	Is it necessary to ground the opposite side of the line: <input type="checkbox"/> Yes <input type="checkbox"/> No		
Do you need to apply for a safety technical measure form for secondary equipment and circuit work: <input type="checkbox"/> Yes, a total of 0 sheets; <input type="checkbox"/> No.			
Other safety measures and precautions: None			
Issuance	Signature of work permit issuer: _____ Signature of the person who co signed the work ticket _____		Time: ___ year ___ month ___ day ___ hour ___ minute Time: ___ year ___ month ___ day ___ hour ___ minute
receive	Signature of the on duty person in charge: _____		Time: ___ year ___ month ___ day ___ hour ___ minute
work do Xu can	Does the safety measures meet the job requirements: <input type="checkbox"/> Yes <input type="checkbox"/> No Safety measures that need to be supplemented or adjusted:		
	Safety measures on the opposite side of the line: Confirmed by the on duty dispatcher (distribution network operation and maintenance personnel) (name) that the opposite side of the line has been executed as required		
	Live parts reserved at the workplace	Live busbars and wires: Live isolation switch (knife switch): Other:	

Figure 2. Factory Station First Work Ticket Template

2) Work ticket process inspection model

(1) Timely delivery rate of work tickets, specific process verification analysis

Scope of application: The first type of work ticket for factory stations

Standard: Sign and send to the operating team before 12:00 on the day before work.

Input content: Screening method: The last work ticket issuance time is less than 12:00 am the day before the planned work start time

Output result: Prompt that the work ticket was not delivered in advance as required

(2) Analysis of Work Ticket Plan Time Verification

Scope of application: The first type of work ticket for factory stations

Standard: The work plan time should be within the approved working time range.

Input content: Screen for power outage application forms associated with the work ticket interface. Go to the power outage application form and find "Approval Information - Approval Work Start Time". The criterion is "Planned Start Time \geq Approval Work Start Time; and Planned End Time \leq Approval Work End Time".

Output result: It indicates that the work ticket is not within the approved scope of the power outage application form.

Work ticket qualification inspection model

Scope of application: The first type of work permit for substation, the second type of work permit for substation, the third type of work permit for substation, the work permit for live work, and the written arrangement record permit.

Standard: The person in charge of the work, the person issuing the work, the person co signing the work, the person receiving the work, the person granting the work permit, and the members of the work team in the work permit should have passed the safety regulations qualification examination and certification.

Input content: There should be a name match in "Power Grid Management Platform ->Operator Management Center ->Operator Management ->Safety Regulations Exam Score", and the status should be "valid", the traffic light should be green, and the score source should be South Power Grid Strong Safety. If the information of the person cannot be found, the judgment is incorrect.

If the information of the person has been found, extract the [Exam Major] and make the following logical judgment:

- 1) The person in charge of the work and the person issuing the work must be either the "three types of personnel" or the "two types of personnel" for the substation.
- 2) The work co signer, work receiver, and work permit holder must be the "three types of personnel" of the substation.
- 3) The members of the work team must be either "three types of people" or "two types of people" or "substation type".

Output result: It indicates that the person in charge of the work permit, the person issuing the work permit, the person co signing the work, the person receiving the work permit, or the member of the work team are not qualified.

V. THE APPLICATION AND SIGNIFICANCE OF WORK TICKET INSPECTION TOOLS

The application of a substation work ticket inspection model based on big data cloud platform enables logical and rule verification of work ticket data, analyzes abnormal work tickets, facilitates the formulation of corrective measures, ensures the correctness and standardization of work tickets, and provides important guarantees for the safety of on-site operations.

A. Application and significance of work ticket filling stage

Figures should have relevant legends but should not contain the same information which is already described in the main text. Figures (diagrams and photographs) should also be numbered consecutively using Arabic numbers. They should be placed in the text soon after the point where they are referenced. Figures must be submitted in digital format, with resolution higher than 300 dpi.

(1) By analyzing the abnormal data of work tickets, it can serve as an auxiliary tool for checking work tickets and discovering errors, greatly assisting work ticket processing personnel. It can also be modified and improved during the work ticket filling stage to ensure the correctness of the next stage of work ticket circulation.

(2) The necessity of controlling work, by comparing the planned time of work tickets with the time of power outage maintenance application forms, effectively analyzing the rationality and necessity of work arrangements, is of great significance for improving the accuracy of power outage schedule and reducing the safety risks of power grid outages.

B. Application and significance of work ticket implementation phase

(1) To ensure on-site safety measures, by analyzing the safety measures data of the work permit, verifying the wiring topology diagram of the power grid management platform equipment, introducing anti misoperation locking logic, effectively judging the correctness of on-site safety measures of the work permit, and reducing personal and equipment risks during on-site operations.

(2) The implementation of multiple review of work tickets, considering the large number of daily work tickets and the significant differences in circulation cycles, mainly analyzes the review time and circulation nodes of each personnel role in the work ticket circulation, effectively judges the effectiveness of personnel review at each node, involves the participation of multiple specialties, and achieves multiple review and control of work tickets[10].

(3) To ensure the timeliness of changes in work tickets, considering the multiple application scenarios, cross operations, and high turnover of external personnel, there are significant changes in the duration, personnel, and work content of work tickets. By comparing and analyzing work plan data with work ticket data, it is effectively discovered whether work tickets have been approved for changes in a timely manner as required.

C. Application and significance of work ticket termination stage

To ensure the restoration of security measures, by analyzing the data on the termination of work tickets and verifying the initial state of the equipment wiring topology diagram on the power grid management platform, the correctness of on-site security measures after the termination of work tickets can be effectively judged to prevent electrical misoperation.

By using the substation work ticket inspection model, utilizing deep data mining and information fusion, and based on the big data cloud platform, a comprehensive screening and analysis of the work ticket business was conducted, covering the entire process and various links of the work ticket business. A comprehensive evaluation was carried out from the work ticket filling stage, implementation stage, and final stage, achieving control in three different stages before, during, and after the incident. The occurrence of safety hazards was comprehensively eliminated, and the efficiency of on-site operations and work ticket applications was improved, which is of great significance for achieving the goal of intrinsic safety.

VI. CONCLUSION

The substation work ticket inspection tool based on big data cloud platform is developed and applied in the context of digital transformation of power grid enterprises. The promotion and application of new technologies such as big data and cloud platform provide new ideas for safety production work, fully utilizing the data of the power grid management platform information system. By building a substation work ticket inspection model, effective data processing and deep data mining have been carried out to achieve the efficiency of substation work ticket inspection, solve the long-standing problem of work ticket review and circulation efficiency, and play a positive role in preventing and handling on-site work safety risks, reducing the occurrence of personal and equipment accidents.

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