Smart Operation and Maintenance Platform of Protection Relay Based on Mobile Sensing and Big Data

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Abstract. In order to solve the current network limitations and human-computer interaction limitations of relay protection and automation in power systems, an intelligent operation and maintenance management platform for electrical secondary equipment based on mobile sensing and big data is proposed. First, the existing problems in the standardization operation and data integration in the relay protection work at this stage are explained, and the significance of the construction of this platform is pointed out. Then the application modes of mobile sensing technology and big data technology in power system is analyzed, proposing the system architecture and functional architecture of the system, and the interaction mode between the mobile terminal and the master station in the system is explained. Finally, the specific functions of the system's standardized operation process and intelligent operation inspection are explained, and the effects of the intelligent operation and maintenance control of the secondary equipment under the original mode and the new mode are compared.

Keywords: Mobile sensing, Big data, Protection relay, Smart operation and maintenance platform

1. Introduction
In terms of power grid development situation, at this stage, the construction of UHV power grid is deepening, the scale of interconnected power grid is expanding, the operation mode of power grid is becoming more and more complex, the penetration rate of distributed power supply is gradually increasing, and the safety and stability of large power grid are becoming increasingly prominent. Traditional relay protection can't meet the needs of real-time changes in the current power grid operating state according to the working mode of setting in advance, real-time operation and periodic verification. This paper proposes an intelligent operation and maintenance platform for relay protection based on mobile sensing and big data.

At present, the research on intelligent operation and maintenance of relay protection is as follows. Literature [1] proposes an intelligent operation and maintenance technology of relay protection equipment based on mobile interconnection. Literature [2] studies relay protection operation and maintenance of 110kV intelligent substation. Literature [3] analyzes the local relay protection operation and maintenance technology. Literature [4] analyzes relay protection operation and maintenance technology based on wireless communication technology. Document [5] designed a relay protection
mobile operation and maintenance system based on multi-dimensional business data fusion. Literature [6] analyzes the intelligent operation and maintenance management of relay protection equipment under the mobile Internet technology. Literature [7] analyzes the faults of system relay protection and the key points of operation and maintenance. Literature [8] analyzes the fault location of power grid operation and maintenance. Document [9] designed a relay protection intelligent mobile operation and maintenance system based on power wireless virtual private network. Document [10] designed an intelligent mobile operation and maintenance platform for relay protection based on power 4G private network. Literature [11] studies the key technologies of intelligent substation relay protection online operation and maintenance system. Document [12] designed a relay protection intelligent operation control system based on big data. It can be seen that there are many researches on platform design, but there are insufficient researches on application of mobile sensing and big data technology.

Different from the above literature research, the current situation of relay protection operation and maintenance as well as the direction of upgrading the operation and maintenance platform are first analyzed. Then, it explains the application of mobile sensing technology and big data technology as well as the construction goal of the system platform, proposes the hardware framework and functional framework of the system, and explains the information interaction mode between the terminal station and the main station. Then, the basic functions and core functions of the platform are explained, mainly including account changes, inspection work, standardization work and version checking. Finally, the prospect and significance of the system construction in this paper are prospected.

2. Current Situation and Problems of Relay Protection

2.1. Influence of deep learning on power grid dispatching

Relay protection operation technology, i.e. secondary operation technology, mainly includes system perception, system prevention and control and system optimization. Relay protection mainly includes the functions of equipment protection and on-line monitoring of secondary equipment status, etc. It realizes the optimization of protection control strategy, protection control and fault analysis. Generally speaking, system perception includes equipment state perception, fault recording and fault location, dispatching technical support system, data acquisition terminal at the station and factory, etc. System optimization mainly refers to relay protection accident countermeasures, intelligent dispatching technical support system, advanced application at the station end, including intelligent state estimation and distributed processing, etc. The prevention and control of the system refers to the analysis of faults by relay protection and the corresponding control strategies to realize the application support of intelligent dispatching technology and the voltage and power generation control at the terminal of the station.

At present, the setting values and various performance indexes of relay protection devices are mostly obtained in an offline state according to the maximum operation mode and the minimum operation mode of the system, and generally remain unchanged in a real-time changing system. However, in the actual system operation, the operation mode needs to be adjusted according to the system operation condition, especially when the system is in some special operation conditions and some protection setting values in the system do not meet the requirements of sensitivity and selectivity, appropriate adjustment must be made, otherwise large-area power grid accidents will be caused. Therefore, at this stage, the intelligent operation and maintenance of relay protection equipment cannot meet the requirements of real-time changes in the system, and it is necessary to continuously improve the intelligent operation and maintenance.

In terms of relay protection control and operation and maintenance, due to the large number of relay protection and safety automatic devices, the maintenance workload of equipment such as primary inspection, scheduled inspection, defect elimination and patrol inspection is large, and with the development of power grid scale, the number of personnel is difficult to match the workload, so the operation and maintenance of secondary equipment is limited to a certain extent. In addition, the number of applications between protection systems is large, and the data acquisition channels are scattered.
There are certain differences among various application scenarios, data management modes and data interaction modes at various levels of scheduling, which makes it difficult to improve the comprehensive application level of relay protection specialty. It directly leads to heavy workload and low efficiency of personnel, lack of corresponding control mechanism for reliability and authenticity of operation results, and inability to use comprehensive and scientific big data analysis to provide accurate support for protection and operation.

2.2. Promotion of relay protection operation and maintenance platform
At present, the development of intelligent substation is advancing continuously. The relay protection operation and maintenance technology in intelligent substation needs continuous innovation and mode change, and finally realizes the intelligent operation and maintenance system characterized by informatization, automation and intelligence, thus realizing the leap from traditional equipment to informatization equipment, from traditional manual inspection to intelligent automatic inspection, and from experience inspection to intelligent inspection. At this stage, the convenience and reliability of power system operation and maintenance are the main indicators reflecting the power system operation and management level. Therefore, it is necessary to make full use of existing resources to build an intelligent dispatching operation and maintenance module with perfect functions, convenient operation and maintenance, and online maintenance, so as to realize the construction and application of an intelligent operation and maintenance management system based on Internet of Things and mobile interconnection technology.

3. Framework of Relay Protection Intelligent Mobile Operation and Maintenance Platform

3.1. Construction target
Based on mobile sensing relay protection equipment, the big data operation and maintenance management platform should make full use of the current mainstream mobile sensing technology, internet of things and big data technology, and combine high-speed communication network and mobile terminal technology to carry out dynamic management of relay protection equipment in substation in the whole life cycle, so as to realize the mobility, automation and intelligence of operation and maintenance work, thus improving the efficiency and reliability of field operation and maintenance work. The system should have a broad spectrum of object-oriented, including dispatching personnel, maintenance personnel, maintenance personnel, etc., through the operation and maintenance of equipment management and control optimization, to achieve safe and stable operation of the power system.

3.2. System architecture
The platform hardware architecture of the system mainly includes a network part and a service system part. The service system part includes two major areas: substation mobile operation and relay protection mobile operation and maintenance application master station. The handheld mobile operation terminal scans and identifies the electronic tags of the operation equipment to obtain the operation, maintenance and other relevant information of the operation equipment, uploads the relevant information to the store's wireless virtual private network, and transmits the information to the safe entry platform through VPN encryption. The platform is connected with the information management area of all levels of power dispatching, and can upload other important contents such as equipment freight information to the area, which serves as the data source for all business systems and the operation and maintenance master station. Then through the switch connected with the information management area, other various services such as database service, application service and the like are realized, and such services include equipment account management, model version management, equipment patrol inspection management, standardization management and the like.

It is characterized in that the application and database service are deployed in the Aliyun virtual service area and are regarded as independent applications of the big data platform. The mobile terminal
access the secure access platform through the power wireless virtual private network and interacts with the application service real-time data through the secure access platform. Intelligent mobile terminal communication adopts operator network, referred to as external network; The mobile intelligent operation and maintenance system is deployed in the information intranet of the power system, and the exchange of data from the extranet and intranet should be handled well.

The main functions of the system include: 1. To realize the collection and management of the account of the substation internal protection equipment and defect information, thus making the past phenomenon of untimely information changes history. 2. Realize the whole process of operation and maintenance work such as patrol inspection, inspection and acceptance of substation internal equipment, and control the whole life cycle process. 3. It is beneficial to the design of secondary equipment such as transformer substation and protection, as well as the storage and management of drawings, product specifications, SCD documents and other filing materials. The main function of the system needs server, mobile terminal, communication network and equipment label to realize.

3.3. Functional architecture
The functional framework of relay protection mobile operation and maintenance platform is shown in the following figure, which is divided into access layer, application layer, data layer and configuration layer. The access layer is mainly divided into Web side and App side. the web side inputs the web address through the intranet to query, thus entering the access. The App terminal enters the network through the wireless virtual private network, and the webpage terminal can mainly view data, export reports, etc., with more detailed functions. App terminal is mainly the function of specific operations performed by on-site operation and maintenance personnel. It monitors and alarms relay protection equipment, secondary circuit, pressure plate, protection status, protection action status, etc. according to relay protection status monitoring information.

The application layer has more detailed functions and is mainly divided into equipment, account management, model version management, equipment inspection management, standardized operation management, defect management, acceptance management, drawing and document data management and advanced application. The application layer functions are deployed in the big data virtual server of
the superior dispatching center. Such applications can meet the requirements of power dispatching personnel, operation and maintenance personnel, and user terminals for mastering relay protection, equipment information and other functions. Through the above application, docking and expansion with other business systems can be realized.

The data layer is the data providing center for mobile operations, and various applications of the application layer depend on various databases of the data layer. The data layer specifically includes all kinds of operation and maintenance operation data, equipment account data, personnel data, organization role data, etc. Such data from PMS system can provide corresponding data support for online mobile operation, thus realizing equipment maintenance and operation and maintenance with offline and online functions of mobile operation.

The configuration layer includes various job template configurations, menu permission configurations, data interface configurations, etc. The configuration layer is the main operation and management center of the application layer and the data layer for the mobile operation terminal, which can facilitate the direct adjustment and operation of the corresponding functional modules by the operation and maintenance personnel.

Figure 2. System function architecture

3.4. Interactive mode between terminal station and main station
Mobile APP is based on system construction such as power wireless private network and secure access platform. The access terminal is a secure mobile operation terminal for operators to use. Security access platform is a unified security protection device for the third-party boundary of system information intranet. It is mainly composed of security access terminal layer, security channel layer, security access platform layer, service access layer, etc. It provides basic functions such as mobile terminal security authentication access, access control, security data exchange and service access. The intranet mobile application back-end service of relay protection operation and maintenance management system is deployed in the information intranet in the form of mobile application service.
Figure 3. System integration mode

The interaction between the mobile terminal and the master station module can be divided into two types: request-response interaction initiated by the mobile terminal and active push mode of the master station module. The direct interaction mode between the mobile terminal and the master station module adopts RESTful interface mode, and the master station module provides RESTful interface service. The mobile terminal realizes the functions of adding, querying, modifying and deleting data by calling RESTful interface.

4. Main Functions of the Platform

4.1. Basic function

Account change requires effective integration of PMS system, relay protection intelligent mobile application, relay protection statistical analysis and operation management system. First of all, it needs to be compared with the account data in PMS management system. The comparison data range includes substation information, interval information, primary equipment information, secondary equipment
information, management unit/operation and maintenance unit/dispatching unit/design unit information, equipment model, manufacturer and other data. Judging whether there is a phenomenon of heart and modification, if so, modifying the account data accordingly, then sending the modified data to the electromechanical protection intelligent mobile application system, judging whether the data is received successfully, updating the account data, realizing data synchronization, and sending the corresponding data to the rest of the accounts, finally realizing data synchronization of the master station and the substation.

The version checking process requires PMS management system and relay protection intelligent mobile operation and relay protection statistical analysis of its operation and maintenance management system. First, the version information of the protection device needs to be imported into the intelligent mobile operation system to form a corresponding configuration information table. The manufacturer, model, version number, check code and other information in the configuration information table are checked with the equipment version checking information to judge whether they pass or not, and the version checking task number is created. After uploading to App, the version is checked to update the version information. The updated version information is stored in the PMS management system and returned to the relay protection intelligent mobile operation and maintenance application system, the relay protection statistical analysis and operation management system, and the version information is sent to the corresponding information table as an update.

![Version verification system process](image)

**Figure 5.** Version review

Patrol inspection process requires the participation of relay protection condition maintenance and auxiliary decision system and electromechanical protection intelligent mobile operation and maintenance system. First, the relay protection intelligent mobile operation and maintenance system issues inspection tasks, including inspection station, inspection type, inspection items, inspectors and inspection time. The task is synchronized and received on the App. After inspection, the operation and maintenance personnel record the inspection results through the App, conduct inspection one by one.
according to the equipment in the APP terminal, fill in the inspection results and problems and upload the corresponding problems to take photos. Upload the patrol inspection results to the main station for review, and judge whether it passes the review. After passing the review, report the patrol inspection data to the summary table, and then push the data to the corresponding auxiliary decision-making system. Evaluate according to the patrol inspection data to form a closed-loop application of the patrol inspection system.

![Patrol operation system process diagram](image)

**Figure 6. Patrol inspection**

Standardized operation process needs the organic combination of relay protection condition maintenance and auxiliary decision system and relay protection intelligent mobile operation and maintenance application system. First of all, the electromechanical protection intelligent mobile operation and maintenance application releases the operation tasks, including equipment inspection, preparation work, work permit, safety measure ticket information, working hours, etc. The task is received synchronously at the App terminal. The operation and maintenance personnel record the operation process and upload it to the main station for review. After the review is passed, the data needs to be verified, reported and summarized. Finally, the data is evaluated in the auxiliary decision system. It can be seen that the basic form of the standardized operation process is similar to that of the patrol inspection operation, with the difference that the specific content of the task is released and received.
Figure 7. Standard practice

The original mode of each basic function and the mobile operation mode pair are as follows.

| Function        | Original model                                                                 | Mobile operation mode                                                                 |
|-----------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Account function| Team members maintain secondary equipment account information in the PMS system at the computer end. If there is any change in equipment information, the change information shall be recorded in paper and brought back to the unit for updating in the computer. | Team members check the data in the handheld mobile terminal on the spot, and modify the data directly in the terminal when inconsistencies are found. The modified data can be synchronized to the mobile operation and maintenance background update ledger, and the mobile operation and maintenance change data line is written back to the PMS system for update. |
| field operation | Team members will print out the operation instructions and carry relevant equipment data to carry out on-site inspection and maintenance operations, and record the results in paper, and bring them back to the unit to enter into the system and make the operation report after the operation is completed. | The work instruction and drawing data are entered into the system according to a certain format. Team members hold mobile terminals to scan the equipment and record the operation results in APP. After the operation, the system automatically generates the operation report according to the paper report style. At the same time, APP supports offline operation mode, which is used to meet the scene without network signals. |
| Job diagnosis   | Team members rely on their personal experience to judge whether the operation results are correct or not. Due to their different professional proficiency, there is the possibility of misjudgment to varying degrees. | Team members set their own checking formula in the system, and when APP records the operation results, the system automatically diagnoses the results according to the checking formula, and gives early warning and prompt to the wrong results in the operation process to facilitate the real-time correction of the operation personnel. |
| Version check   | Judging whether the version information of the equipment meets the network access requirements by manually querying the information table, and notifying the team offline to upgrade or change the version if it does not meet the requirements. | The information table is imported into the system to form a unified version information standard library. The system automatically compares the check code of the equipment with the version library, screens out the equipment whose version information does not meet the network access requirements and synchronizes to the APP end. Team members can carry the mobile terminal to check the version information again on site and upgrade the version. |
4.2. Core function

1. Cross-system integration of protection specialties

When a power grid fails, the relay protection fault information system can send a large number of fault information such as protection action events, protection wave recording files and wave recorder wave recording files sent within the range of fault points, as well as isolation switch and circuit breaker information from SCADA, and filter the fault file through corresponding application of the master station system. The system can realize such fault diagnosis and logic analysis, judge the power failure area based on fault hypothesis through corresponding protection data, and also realize self-diagnosis of protection setting value. In the aspect of integration of protection specialty and other systems, it can assist intelligent mobile operation and maintenance App in-situ inspection by combining automatic remote inspection of secondary equipment online monitoring, realize online monitoring of data and automatic filling of data, assist secondary online monitoring system in verifying discovered defects through equipment operation data recorded by mobile intelligent operation and maintenance App, and send the verified defects to superior operation and maintenance departments for defect elimination.

2. Visualization of data

The secondary data information of the power system is characterized by large complexity and real-time changes, especially the configuration of relay protection parameters of various equipment is quite different. Relying on traditional methods to directly analyze the secondary equipment data is inefficient, and it is difficult to obtain important information about protection parameters in time. Through this system, visual data display technology, computer graphics and image processing technology are used to convert the data into images. Direct display at App and computer terminals and integration of interactive processing theories and methods can realize dynamic display of all services such as online operation information, historical action information, defect information, overhaul information, etc. of protection equipment, thus realizing development and application of functions such as defect diagnosis, risk early warning, status evaluation, etc. of equipment. It is also conducive to improving the reliability of the system. Operation and maintenance personnel can improve the analysis capability of multiple data by using big data technology, realize comprehensive analysis of equipment life cycle from point to surface, and grasp various information of equipment through data visualization.

5. Prospect of Platform Function

The construction of mobile operation and maintenance platform for relay protection proposed in this paper can combine the account base of PMS relay protection account with the labeling of relay protection physical ID tag, realize the correlation between equipment data and account, and manage the wrong and missing account, thus effectively improving the integrity and accuracy of electromechanical protection equipment account.

The system in this paper can also promote the mobility and informatization of the secondary inspection and maintenance work, and obviously improve the operation efficiency. The secondary inspection and maintenance work based on mobile terminals can realize the networking and informatization of the operation and reduce the reports of traditional inspection. The input link and the data checking link can save the time for the second inspection, realize the standardization of the second inspection and maintenance, formulate the template, standardize the management and statistical input of the maintenance report account, realize the automatic archiving of data and reports and the management of abnormal data, and form the electronic and digital database of historical inspection and inspection reports.

Through the mobile application system, a unified version library can be more conveniently and quickly constructed, secondary operation mode transformation can be promoted, a unified version library of relay protection across the network can be formed, effective control of version information can be promoted, and on-site verification of version information of protection equipment by mobile terminals based on App can be realized. It can effectively control the correctness rate of new network access and existing protection equipment versions, and provide corresponding technical support for protection defect rectification and accident countermeasures rectification.
6. Summary
This paper proposes an intelligent operation and maintenance management platform for relay protection based on mobile sensing and big data technology. Firstly, the current situation of relay protection operation and maintenance and the direction of upgrading the operation and maintenance platform are analyzed. Then, it explains the application of mobile sensing technology and big data technology as well as the construction goal of the system platform, proposes the hardware framework and functional framework of the system, and explains the information interaction mode between the terminal station and the main station. Then, the basic functions and core functions of the platform are explained, mainly including account changes, inspection work, standardization work and version checking. Finally, the prospect and significance of the system construction in this paper are prospected.

References
[1] Qian Hai, Jia Songjiang, Yang Fei, et al. Research on Intelligent Operation and Maintenance Technology of Relay Protection Equipment Based on Mobile Interconnection [J]. Smart Power, Vol. 47 (2019) No. 11, p. 60-66.
[2] Li Ming. Research on Primary Electrical System and Relay Protection Operation and Maintenance of 110kV Smart Substation [J]. Engineering Technology Research, Vol. 4 (2019) No. 23, p. 155-156.
[3] Zhang Wuyang, Wang Tong, Su Xinran, et al. Research on Operation and Maintenance Technology of Localized Relay Protection [J]. Northeast Power Technology, Vol. 40 (2019) No. 10, p. 48-50, 53.
[4] Lu Xiaorong, Xie Dan. research and application of relay protection operation and maintenance technology based on wireless communication technology [J]. Science and informatization, (2019) No. 34, p. 33.
[5] Zeng Zhian, Liu Hui, Tang Xiaobing. Design and Implementation of Relay Protection Mobile Operation and Maintenance System Based on Multidimensional Business Data Fusion [J]. Power Big Data, Vol. 22 (2019) No. 11, p. 29-37.
[6] Zeng Zhian, Yao Shuyou, Zheng Xiaoling, et al. Discussion on Intelligent Operation and Maintenance Management Mode of Relay Protection Equipment Based on Mobile Internet Technology [J]. Power System Protection and Control, Vol. 47 (2019) No. 16, p. 80-86.
[7] Duan Yufeng, Jia Shuaijie. Analysis of power system relay protection faults and operation points [J]. Encyclopedia Forum Electronic Journal, (2019) No. 8, p. 348-349.
[8] Sun Mengchen, Congwei, Yujiang County, et al. Fault Location Method for Relay Protection Communication System under the Background of Power Grid Operation and Maintenance Big Data [J]. Power Automation Equipment, Vol. 39 (2019) No. 4, p. 141-147.
[9] Cui Yu, Wu Yi, Zhang Zhi, et al. Design and Implementation of Relay Protection Intelligent Mobile Operation and Maintenance System Based on Power Wireless Virtual Private Network [J]. Power System Protection and Control, Vol. 46 (2018) No. 23, p. 175-181.
[10] Zhang Yuguan, Zhang Jigang. Application of Relay Protection Intelligent Mobile Operation and Maintenance Platform Based on Power 4G Private Network [J]. Communication Power Technology, Vol. 35 (2018) No. 1, p. 110-111,114.
[11] Dujun, Xiang Ye, Ge Liqing, et al. Research and Implementation of Key Technologies for Online Operation and Maintenance System of Relay Protection in Smart Substations [J]. Power Automation Equipment, Vol. 36 (2016) No. 7, p. 163-168,175.
[12] Sheng Hailhua, Wang Delin, Ma Wei, et al. Research on Intelligent Operation Control System of Relay Protection Based on Big Data [J]. Protection and Control of Power System, Vol. 47 (2019) No. 22, p. 168-175.