Design of Intelligent Operation and Inspection Management System for Power Grid Equipment Based on Full Business Data Center

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Abstract. There are some problems in the existing operation and inspection systems of State Grid Corporation of China, such as low level of system data integration, poor degree of functional application practicality. In order to solve these problems, the intelligent operation and inspection management system for power grid equipment has been designed based on full business data center. This system complies with the overall deployment requirements of the Internet of Things, including sensing layer, network layer, platform layer, and application layer. Based on the unified storage and management of the full business data center, the integration and service call of data information from 14 sets of operation and inspection systems could be realized. As a result, holographic perception of equipment status, active fault warning and prediction, and intelligent generation of operation and inspection decision could be realized by the designed system, which can promote the transformation of operation and inspection mode from business process driven to equipment status driven.

1. Introduction
With the rapid growth of the scale of power grid equipment, it is the only way for the development of operation and inspection specialty to actively explore intelligent operation and inspection technology and improve the technical level under the condition that the number of operation and inspection personnel cannot grow synchronously [1-3]. The intelligent operation and inspection management system for power grid equipment has been proposed to be constructed by State Grid Corporation of China in 2016, and the integration of Plant Management System (PMS), Operations Management System (OMS) and other professional system data can be realized [4-5]. This system is based on Internet of things (IOT), mobile Internet, cloud computing, big data and other modern information network technologies [6]. The version uniformly promoted by State Grid Corporation has been put into operation in Shandong province power grid in 2018. However, in the application process of the system, it is found that its system integration, business application, function expansion, user experiences and other aspects need to be further improved. Such as data update delay, response lag, system function fusion degree is not enough. This is because most of its data is directly connected to the original business data system. These problems can be effectively solved by upgrading the original system based on the full business data center.

The full business unified data center is the further development and improvement of the existing data center of State Grid Corporation, including data processing domain, data analysis domain and...
data management domain [7]. Data processing domain is the center of data storage, processing and integration of various businesses in the process of production, operation and management. Data analysis domain is the collection center of all business, all type and all time-dimension data, providing complete data resources, efficient analysis and calculation ability and unified operation environment for all kinds of analysis and decision-making applications. The core of data management domain are the construction of unified data model, and the construction and application of enterprise level master data. Through the unified planning and control of data definition, storage and use, it provides support for data integration and application across disciplines and systems.

Therefore, intelligent operation and inspection management system for power grid equipment based on full business data center has been designed in this paper. Compared with the original system, the unified storage, application and management of data and application can be realized by the full business data center, which will improve the unification and specification of the integration, model building, data access, and service call.

2. Architecture Design
The architecture design of the intelligent operation and inspection management system complies with the overall deployment requirements of the IOT. It includes sensing layer, network layer, platform layer, and application layer, and more details are further refined, as shown in Fig. 1.

2.1. Sensing Layer
The sensing layer is composed of all kinds of IOT sensors and edge IOT agents, which are constructed and maintained by each business subsystem. All kinds of IOT sensors, including device sensors, environmental early warning sensors, public service sensors, are used to collect different types of state parameters. Edge IOT agents are mainly used to realize the aggregation of sensor data, edge computing and Intranet return within a certain range.

2.2. Network Layer
The network layer is composed of communication channels, such as power wireless private network, power APN channel, power optical fiber network and related network equipment. These channels can provide high reliable, high security and high bandwidth data transmission.

2.3. Platform Layer
The platform layer has three functions, which are IOT device management, edge computing configuration and IOT data storage. The open access and mass data storage of multi-source heterogeneous IOT data are mainly realized by three aspects. The first aspect is the management, coordination and monitoring of various sensors and node devices of the IOT. The second aspect is to configure the edge computing algorithm of the IOT remotely. The last one is data sharing with ubiquitous power IOT. According to the design idea of big platform and micro service, the platform layer is composed of IOT management center, business systems, full business data center, regulatory cloud and enterprise middle platform.
The IOT management center collects the sensing layer data and provides multi-dimensional data for the full business data center. Massive directly connected intelligent business terminals and edge IOT agents can be monitored, configured and managed by the IOT management. In addition, it can also rapidly iterate and remotely upgrade the intelligent applications of various disciplines, and collect a large amount of collected data and standardize the processing. Finally, the IOT management center can build an open and shared application ecosystem to support the data access of the stock business system. The full business data center provides unified data access, mining services, analysis services and application business data sharing services for all kinds of analysis applications in the intelligent operation and inspection management system. The regulatory cloud is a platform that inherits the existing achievements of interconnection between PMS and OMS, and deepens the data channels and scope of large-scale operation and overhaul system operation. The regulatory cloud provides data interaction with full business data center. It can provide data such as power grid topology, remote signaling, remote alarm, fault trip, overshoot, measurement, remote control operation record, and AVC operation record. Furthermore, the regulatory cloud also can provide load analysis and other source end calculation results data.

Enterprise middle platform is the natural evolution of the full business data center platform. It is a system composed of a series of business capability standards, business analysis methodology, configuration management and execution system and operation service team. Data center is an ecosystem based on the full business unified data center, which provides data sharing services to the outside world through capacity precipitation and service encapsulation on the basis of data aggregation, unified specification and global connectivity. Business middle platform is positioned to provide shared services for core business processing and support front-end applications to achieve rapid and flexible construction. In the business middle platform system, through the integration of power grid business
services, lightning business services, GIS business services and meteorological business services scattered in various disciplines, common business services can be formed, such as model maintenance services, topology analysis services, lightning prediction services, lightning information services, road network services, positioning services, meteorological monitoring, and disaster early warning. These services can support the rapid and flexible construction of intelligent substation management, intelligent transmission analysis management, intelligent transportation inspection analysis, big data analysis of transportation inspection equipment and other businesses. At the same time, with data services as the link, the enterprise middle platform can improve the ability to support the organic collaboration of business resources in the application scenarios of intelligent operation and inspection management system.

2.4. Application Layer
The application layer is used for advanced data analysis application and supporting operation inspection business management. Through the establishment of a unified global data model, the use of big data, artificial intelligence and other technologies, to achieve the holographic perception of power transmission and transformation equipment, active warning of operating conditions and intelligent efficient decision-making.

3. Data Access
Based on the customized model of sg-cim3.0, the intelligent operation and inspection management system integrates 14 sets of operation inspection information systems data from the sensing layer data information sources, as shown in Table 1. According to the system properties, these systems can be divided into fusion analysis systems and source sensing systems.

Fusion analysis systems, including substation auxiliary equipment monitoring system and regulatory cloud system, is mainly connected with multi-dimensional fusion analysis grid resource information such as grid operation information, substation equipment status monitoring information. There are two kinds of data access methods. One is that the intelligent operation and inspection management system directly invokes the control cloud service, the other is to push the service to the full business data center and synchronize the data to the full business data center for storage. Based on the web service technology, the full business data center accesses the relationship data and picture data of the monitoring system of the substation equipment and its integrated original service systems in real time. Relational data are stored in distributed database of big data platform, and picture data are stored in distributed file systems of big data platform.

Source sensing systems, including pms2.0 system, line channel visual remote inspection system, 3D data center and other 12 sets of information systems, mainly access to four categories of grid resource information, including grid operation and inspection information, transmission equipment status monitoring information, operation environment information and 3D model information. Based on OGG database synchronization technology, real-time access to pms2.0 system data, line channel visual inspection system relationship data, environmental pre class system all data to big data platform of the full business data center distributed database. Based on the unstructured data interface service, the distributed file system of the big data platform in the full business data center can access the unstructured data such as pictures in the line channel visual remote inspection system.
Table 1. Formatting sections, subsections and subsubsections.

| No. | Access systems                                              | Data information                                                                 |
|-----|-------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1   | Regulatory cloud system                                      | Device model information, Grid operation information, Outage planning information, Equipment alarm information, Operation event handling information |
| 2   | Substation auxiliary equipment monitoring system            | Auxiliary equipment monitoring information, Robot patrol information, Video monitoring information, Equipment status evaluation information, Equipment live detection information, Equipment online monitoring information |
| 3   | PMS2.0                                                      | Patrol information, Account information, Test information, Defect information, Two ticket information, Maintenance information |
| 4   | Visual remote inspection system of line channel             | Device account information, Image result information, Warning information         |
| 5   | Distributed fault monitoring and intelligent diagnosis system for transmission lines | Device account information, Fault result information                              |
| 6   | High voltage cable lean management integrated platform      | Ontology online monitoring information, Environmental information of cable tunnel, Cable tunnel robot information |
| 7   | Comprehensive monitoring and early warning system for power grid disaster prevention and mitigation | Real time meteorological environment information, Information of dangerous chemical explosion disaster |
| 8   | 3D data center                                              | Three dimensional model information of substation (converter) station, Three dimensional model information of transmission line, Basic geographic data of transmission channel, Transmission channel point cloud data |
| 9   | Power quality online monitoring system                      | Energy availability information, Outage information                               |
| 10  | Lightning location system                                   | Time-sharing and color separation lightning information, Line channel and area lightning information |
| 11  | Icing warning system                                        | Equipment icing range information, Ice cover warning information                 |
| 12  | Mountain fire monitoring system                             | Thermal power information, Warning tower information, Thermal power hazard level information |
| 13  | Typhoon warning system                                      | Typhoon warning information, Typhoon tracking information                        |
| 14  | Numerical weather forecast system                           | Meteorological early warning information, Weather forecast information, Meteorological historical data information |

4. Data Storage Design
The full business data center provides unified data access services, mining services, analysis services and business data sharing services for all kinds of analysis applications in the management system. Data analysis domain divides business source data into structured data, unstructured data and collected measurement data according to data format and business type. In the data source business system, unstructured data are stored in the big data platform, and structured data and acquisition measurement data are stored in the paste source history area. Based on the whole domain data model and the source business system model, the theme domain division, multi-source analysis and calculation are carried out for the data in the paste source history area to form the detailed and summary data to be stored in the data warehouse. Based on the business requirements of the data warehouse and the management system, a data mart for the function modules of the intelligent operation and inspection management system is created, as shown in Fig. 2.
Data analysis domain divides business metadata source data into structured data, unstructured data and 3D data according to data format and business type. 14 sets of data source systems will be migrated to the full business data center analysis domain, and microservice reconstruction will be carried out simultaneously. According to the principle that the structure of data storage table remains unchanged, the paste source historical area stores the structured historical data and the collected measurement historical data in the source business systems for a long time. In order to eliminate the influence of shielding on the source system when tracing the data source, ETL Technology is used to extract the source business data to the paste source history area. Based on the global data model, the data warehouse divides the cleaned and transformed paste source historical area data into subject areas and stores the summary data under certain business conditions. Based on the summary and detailed data of data warehouse, data mart can store the analysis data for the function module of intelligent management system.

5. Conclusions
In this paper, an intelligent operation and inspection management system for power grid equipment has been designed. By accessing 14 sets of information systems, comprehensive integration of multi-source system data of operation inspection has been accomplished. By means of intelligent equipment, channel, operation and maintenance, maintenance and production management, the problems of traditional operation and inspection mode in information acquisition, state perception and human based operation mode the system can be solved. As a result, the ability of equipment state perception, active prediction and early warning, auxiliary diagnosis and decision-making, and intensive operation and inspection control will be improved.

References
[1] Wang D., Zhou Q. (2016) A Method of Distributed On-line Analytical Processing of Status Monitoring Big Data of Electric Power Equipment, Proc. Chinese Soc. Electr. Eng. (CSEE), 36: 5111-5121. (in Chinese)
[2] Jun H., Liqun Y., Zhen L., Lijuan G., Lian D., Yubo Z. (2017) Fault Diagnosis Method of Transmission and Transformation Equipment Based on Big Data Mining Technology, High Volt. Eng., 43: 3690-3697. (in Chinese)
[3] Xiaqin C., Le L., Feng Q., Zhong X., Junxiang L., Tianwei X. (2017) Intelligent Location and Analysis of Power Grid Fault Trip Based on Multi-source Data, Energy Procedia 141: 580-586.
[4] Nasri S., Slama S.B., Yahyaoui I., Zafar B., Cherif A. (2017) Autonomous hybrid system and coordinated intelligent management approach in power system operation and control using hydrogen storage, International Journal of Hydrogen Energy, 42: 9511-9523.

[5] Jihong T., Canlin W., Xinfan J., Jianhui Y., Feilai P. (2018) The construction of power grid operation index system considering the risk of maintenance, 3rd International Conference on Advances in Energy Resources and Environment Engineering.

[6] Xiwei W., Chao L., Qiwei G., Huijun H., Yan S. (2017) Research on Condition Monitoring and Fault Diagnosis System of Relay Protection for Intelligent Substation, Shandong Electric Power, 44: 55-57. (in Chinese)

[7] Weichang Z., Jian R., Xiufang J., Xiangjun M. (2018) Research on Matrix Connection Evaluation Method for the Cost of APTTDS, Shandong Electric Power, 45: 6-9. (in Chinese)

[8] Xinghua X., Bo Y. (2019) The Development of Intelligent Individual Soldier Equipment for Power Transmission Maintenance, Shandong Electric Power, 46: 57-60. (in Chinese)