Design of Distribution Automation Master Station System Integration Scheme Based on "n + 1" Architecture

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Abstract. More and more network and provincial companies within the State Grid have adopted the "n + 1" architecture, that is, the deployment of production control at the regional and municipal levels, and the centralized deployment of information management at the provincial level to build the distribution automation master station system. The main station system of information management regional can independently evolve into the distribution cloud main station. In response to the construction trend of "n + 1" architecture, an integrated scheme of distribution automation master station system based on "n + 1" mode is proposed, and it is verified and analyzed on the new generation of distribution master station system constructed by State Grid Ningxia Electric Power Company. The verification and analysis on the above show that this integrated solution can solve the problems of cross-regional data synchronization and distributed data storage based on the "N+1" mode of the power distribution master station system, while avoiding the repeated construction of the information management area. At the same time, this construction mode can reduce operating costs, improve the efficiency of distribution network data utilization. At present, this scheme has been applied in Sichuan, Inner Mongolia, Jiangsu and Shanghai Electric Power Company, has a strong demonstration.

1. Introduction

The distribution network is the last link of the power system to supply power to users. It is an important link between the power grid and users [1-2], and it is also the key infrastructure of the city. Distribution automation is an important technical means to improve the management level of distribution network production and operation, and also will improve the reliability of power supply [3-4].

Since 2009, State Grid Corporation has successively launched "N+N" (decentralized deployment of production control areas and management information areas) and "1+1" (centralized production control areas and management information areas) deployment method of the distribution automation master station system construction. Among them the "1+1" mode only has a construction case in Beijing. Compared with the current situation that many network provincial companies have already carried out large-scale construction in the distribution master station production control area, the difficulties of transformation make it is tough to meet the needs of various prefectures and cities for local development of regulatory business [5]. However, the "N+N" model has relatively high investment, low maintenance efficiency and poor technological advancement. At the same time, looking at the models of power distribution master stations in various provinces, there is rarely a provincial power company using the same manufacturer and model of the power distribution master
station system [6]. At present, within the scope of State Grid and China Southern Power Grid, there is no precedent for the construction of "N+1" mode power distribution master station system. Based on this, the centralized deployment of provincial management information based on the existing power distribution master station of the municipal company meets the needs of the market, and the new generation of power distribution master station system of the "N+1" mode has more vitality and promotion space [7]. In reference [8], introduces the system positioning of distribution automation master station system for dispatching. All data information and function realization are basically realized in the production control area. It does not have the ability to support cross regional business, and the construction of information management area of distribution master station has not been carried out. Reference [9] proposes that the distribution automation master station system is mainly positioned to serve the large-scale operation of the distribution network real-time monitoring and dispatching management, and the application considerations such as terminal management, line overload analysis, and single-phase ground fault detection for operation inspection services Insufficient, it does not have the function of data mining for distribution automation operation, and it is difficult to provide better support for economic operation of the distribution network, loss reduction, adjustment, planning operation mode, and improvement of the utilization efficiency of power distribution equipment. Reference [10] discusses the distributed integrated modeling technology of distribution automation master station. The establishment of real-time communication mechanism in distribution system can meet the functional application of operation monitoring and state control of distribution automation master station. Reference [11] analyzes the composition of the information acquisition system and the development status at home and abroad, and puts forward the key technologies of the information acquisition system,

This article proposes a distribution automation master station system integration scheme based on the "N+1" architecture, and carried out a pilot test at the State Grid Ningxia Electric Power Company. After a year of operation, the scheme can solve distributed data Technical problems such as storage and the type of multi-to-one cross-regional data synchronization, and achieve distribution operation status management and control applications and distribution network management penetration requirements, supporting the operation and control operation of distribution network., production operation and maintenance management, status maintenance, fault repair, defects and hidden danger analysis and other business development [12-13].

2. System overall architecture
The provincial power distribution master station mode based on the "N+1" architecture refers to the unified deployment and unified operation and maintenance of the functions of the distribution automation master station management information area in the provincial company. The application functions of the distribution network of each city are logically independent from other cities and do not affect each other [14-15]. The function of the main distribution station in the production control area still adopts the prefecture-level deployment method [16], and the two parts of data are organically integrated to meet the operation monitoring and operation status control requirements of the distribution network [17-18]. The overall architecture diagram is shown in the figure 1:
The provincial power distribution master station mainly includes the information management regional power distribution master station system and the information exchange bus, which is responsible for the data acquisition of distribution transformer terminal of all public network communication in the province, and the function realization of distribution network operation status control. Deploy the interface adaptation server to realize the information interaction with the electricity consumption information collection system, the State Grid distribution automation index analysis system, the massive data platform, the distribution network intelligent operation and maintenance management and control platform. At the same time, the grounded municipal power distribution main station system can be realized Cross-regional data synchronization, model synchronization and so on, to achieve the collection of data across the province [19].

3. The overall design thought of "N+1" system

3.1 Unified planning and coordinated development
Clarify the positioning of the distribution automation master station system, closely combine the top-level design requirements of the “intelligent perception, data fusion, and intelligent decision-making” of the State Grid Corporation’s smart distribution network, plan and coordinate the development of the distribution master station system, PMS2.0 system and distribution construction of a smart operation and maintenance management and control platform for the power grid. Among them, the distribution automation system is an important part of the intelligent perception of the distribution network. As the main direction, the distribution network dispatching monitoring and the distribution network operation status collection, supporting the dual business of the distribution automation service overhaul and the operation Point-to-face power distribution automation covers the whole province, supporting comprehensive management and control from operation monitoring to power grids and equipment.

3.2 Adjust measures to local conditions and improve the structure
Fully consider the current large-scale deployment and construction projects in many network
provinces, companies, and municipal production control areas, the economic considerations of regional
distribution automation construction investment, adopt the "N+1" method to implement a new
generation of power distribution master stations according to local conditions upgrade construction.
The master station construction mode fully considers the convenience and standardization of system
maintenance, so that the master station construction within the province’s company has "unified
functional applications, hardware configuration, interface methods, operation and maintenance
standards."

3.3 Perfect interaction and full sharing
Share the distribution network operation data collected by the distribution automation system with
PMS2.0, distribution network line loss management system, distribution network intelligent operation
and maintenance management and control system and other business systems to ensure that the
distribution automation system is maintained with the PMS2.0 graphical topology Consistent, support
the simultaneous line loss management of the distribution network, the active repair management of
PMS2.0, and realize the comprehensive monitoring and deep application of information such as low
voltage, heavy overload, and equipment failure.

3.4 Strengthen information security protection
Install positive and negative physical isolation devices between the distribution automation main
station system and the main network EMS system to ensure the information security of the main
network EMS system and the dispatch data network. Optical fiber communication stations and
wireless public network communication stations are connected to the main station of the distribution
automation system through the safe access zone to prevent the intrusion of the communication from
the terminal into the main station system, and realize the collection application of the sub-safety zone
of the distribution automation main station system. Remote signaling, telemetry, remote control)
terminal data is connected to the production control area collection application part through the secure
access area, and the second remote (remote signaling, telemetry) terminal data accesses the
management information area through the security isolation component.

4. “N+1” System data architecture

4.1 Graphical data flow
The provincial power distribution master station builds the whole grid analysis function based on the
integrated network model for deployment. The main network part of the basic diagram module comes
from the dispatch automation system (EMS), and the medium and low voltage diagram module comes
from the PMS2.0 system. The two parts of the information are spliced in the production control area
through the graphics import tool through the exchange bus. When the dispatcher confirms the diagram
and model, the module information will be released as black chart, and then the local will synchronize
to the database server of provincial distribution master station through Kafka. The unqualified data
will be fed back to the corresponding data source system and re-imported after correction. The
Schematic diagram of data flow of power distribution master station is shown in the figure 2:
Figure 2. Schematic diagram of data flow of power distribution master station

4.2 Model distributed management architecture
Because there is no management information area at the city end of the distribution master station of “n + 1” mode, the graph and model data of all cities are synchronized to the provincial management information area. Therefore, it is necessary to divide the province model according to the organization of the model ID, and the device ID area number is subdivided into cities and districts and counties according to management responsibilities, so that the distribution network equipment of different areas can be distinguished by recording ID model. Various real-time data corresponding to the equipment model are also distinguished accordingly. As shown in Figure 3, each application can distinguish cities, counties and districts based on the device ID area number, so as to data partition management and application distribution can be achieved on a unified cloud platform.

Figure 3. Model distributed management architecture diagram
4.3 Real-time data streaming
The private network communication distribution terminal, public network communication DTU/FTU/fault indicator are connected to the production control area of the power distribution master station of the city electric company through the safe access area, and the wireless public network communication method distribution terminal and other power distribution status collection. The devices are integrated into the provincial-level power distribution master station management information area. The real-time data flow diagram is shown in figure 4.

![Figure 4. Real-time data flow diagram](image)

Data in the production control area: All power distribution terminals that require private network communication transfer data to the security production area through the private network collection server deployed in the security access zone, and the "two remote" terminals and fault indicators are deployed in the security access zone. The wireless collection server in the zone transmits data to the security production area, and the security production area front-end server performs data processing; the vertical encryption authentication gateway is deployed in the zone I and has the ability to cross physical isolation.

Data in the management information area: The intelligent power distribution station area of public network communication transmits data through the public network acquisition server deployed in the management information area and performs data processing.

All remote control commands are only allowed to be issued in the production control area, and cross-region data exchange is carried out through the information exchange bus and physical isolation of forward and reverse directions.

A positive and reverse physical isolation device is added between the main distribution network systems, the main network real-time data and operating information are transmitted to the distribution network master station, and the distribution network master station remotely controls the 10kV substation outlet switch command to directly issue the substation or send it to the main through reverse isolation network system.

4.4 Interactive data flow
4.4.1 Interact with the grid dispatching control system. The power distribution master station can obtain the measurement and status information of the 10kV voltage level related equipment of the substation through the data transmission method of the power grid dispatching control system, and support the synchronization of the signboard information of the power grid dispatching control system. The real-time data interaction between the power distribution master station and the power grid dispatching control system shall be connected through the safety equipment of the forward and reverse physical isolation device.

4.4.2 Data interaction with provincial management information area. (1) Overall structure
The "N+1" architecture of the power distribution master station system due to its multi-to-one structural particularity, the conventional synchronization methods based on files, real-time database, and commercial database are no longer applicable, while the kafka synchronization method based on the distributed message processing mechanism It happens to be a good solution to this problem.

By adding a kafka server for provincial communication in the main station of the city, each application in the main station communicates with the kafka service of this system, and the kafka service in the Local power company system is coordinated with the kafka service of the provincial power company to complete the provincial integration. Do not carry out structural transformation of the existing main station of the Local Power Company the overall structure is as shown in figure 5:

![Figure 5. The overall architecture diagram of Kafka synchronization](image)

Kafka provides information transmission channels across isolation and across provinces for various applications. The two systems of province and local are based on application-layer interaction, and there is no need to pay attention to transmission link issues. Figure 6 shows the cross-region interaction of graph, modulus, number and other data through Kafka.

![Figure 6. The data flow diagram of Kafka synchronization](image)
For single application data exchange, the sending program can be deployed in the sending side system (such as local power distribution master station), and the service data will be serialized and sent to the receiving side system (such as the provincial power distribution master station) through Kafka deserialize the data block, as is shown in figure 7, and import it into the system for subsequent processing and application.

![Figure 7. Data synchronization of single application](image)

(2) Business data interaction design

For business-oriented data exchange, a unified object identification is used as the basis for the integration of the provincial and local systems, and the rdf_id signal should be used for object identification. When exporting system data from the source, the system private identification should be converted into a unified object identification. On the contrary, when importing, the target system will convert the unified object identification into a system private identification. In particular, when considering the implementation of the program, from the perspective of efficiency, for a homogeneous system, consider using private identification (adding regional information to prevent conflicts between cities). The data serialization requirements are similar to the device object identification requirements. For heterogeneous systems, public serialization and deserialization methods (such as Protobuf) should be used to jointly define the data structure recognized by both parties. The types of business data interacted between provincial and local systems are as shows in figure 8:

![Figure 8. The business data flow of cross-region synchronization](image)

➢ Historical sampling data synchronization

As shown in Figure 9, the historical sampling data is sent to the cloud master station in a message synchronization mode. The main process consists of four parts: (1) The historical data of production control area and management information area are synchronized through the commercial database synchronization mechanism; (2) the incremental data during the period of time is regularly extracted from the commercial database of management information area; (3) based on fixed messages Format,
the incremental data is transmitted to the cloud master station through Kafka; (4) The cloud master station deploys a message receiving service, receives Kafka messages, and calls the opentsdb interface to write the incremental data into OPENTsdb.

![Figure 9. Cross-region synchronization service data flow of historical sampling](image)

- **Historical alarm synchronization**

  The alarm query and forwarding program is deployed in the management information area of Distribution automation master station. By querying the historical alarm information of the alarm log-in table, after conversion processing, the relevant alarm information required by the cloud system is sent to the cloud system through the Kafka message service and stored in the management information area master station. The alarm is being stored. Alarm synchronization only involves the conversion of feeders and equipment codes. These IDs in the uploaded data should be converted to corresponding IDs in the cloud. The mapping relationship between the two IDs is saved in a file on the DMS side and updated regularly.

  Alarm synchronization uses google's Protobuf to serialize and deserialize interactive data between the source and the cloud. The distribution automation master station system needs to install and deploy the dynamic library of Protobuf (version 2.5.0) on the management information area synchronization node. The data collection and uploading function refers to the process of preparing and uploading serialized alarm data by local and municipal companies. The local power companies need to prepare the alarm data to be sent by their respective systems according to the regulations of the provincial master station. Contains common alarm data such as switch displacement and protection actions. Using Protobuf to serialize alarm data can effectively solve data exchange problems in heterogeneous environments. Protobuf is a portable and efficient structured data storage format, which is platform-independent, language-independent, and extensible.

![Figure 10. Architecture diagram of provincial -local alarm integrated processing](image)
Message synchronization

As shown in Figure 11, the production control area message is sent through the message bus, and the local message synchronization process sends the message of the designated channel to the management information area according to the configuration. The basic platform of the management information area configures the message synchronization receiving program. After receiving the message of production control area, the bus will deliver to different applications according to the channel subscription information. The management information area application processes the message, and if it needs to be saved in KAFKA, it calls the message interface of Kafka.

![Figure 11. Message synchronization architecture diagram of provincial-local master station](image)

5. Application cases

Facing the scale and application requirements of the distribution network at the end of the 13th five year plan in Ningxia, with the goal of "improving intelligent dispatching control, strengthening lean operation and maintenance, and realizing information security protection and reinforcement”, and based on the architecture requirements of the new generation distribution master station system, it is necessary to make full use of the connection between the current local system and the new generation of distribution automation master station system in the information management area constructed by the provincial company, "N + 1" deployment mode is adopted to upgrade the distribution main station in the whole area.

In May 2018, Ningxia Electric Power Company of State Grid launched the construction of a new generation of "N+1" architecture power distribution master station system. Six local power company, including Yinchuan and Shizuishan in Ningxia established production control regions, relying on Ningxia Xintong Company to establish provincial management information area, which was fully completed in December 2019. Up to now, the management information area has completed the synchronization of graphics, real-time data, history alarms data and other data. The specific data is as follows: Distribution network under the control of Ningxia Company Distribution Network there are 1,765 10kV lines, with a total of 13730 power distribution terminals, including 3142 three-remote terminals and 10,588 two-remote terminals. Among them, the main station of the provincial management information area directly connects 794 transient fault Indicators. There are 450 Intelligent convergence terminals, with a total of 457,070 remote signals, 839,735 telemeters, and 20146 remote controls. The feeder automation mode is centralized and on-site, including 533 centralized automatic FA inputs and 1,060 on-site FA inputs.

From the data of the system running for one year, the system can display the location map information of the province, the monitoring of the distribution operation of the day, the basic operation index of the distribution network of the current month, etc., also to show the real-time overview of the distribution network. And through statistical analysis of historical data of key indicators, the province's data can be accessed, and the distribution network status control and other services can be effectively supported.
6. Conclusion
This paper takes the construction of a new generation of distribution automation master station system suitable for the construction of a new local-saving integrated deployment model as the starting point, and proposes a design and application of a distribution master station system integration scheme based on the "N+1" architecture. Design ideas, data flow and cross-region synchronization, etc., to realize the mining of distribution automation operation by expanding the application functions of information management in a large area, which can delay investment in the distribution network, ensure the operation of equipment, and in economic operation, loss reduction. Adjust the operation mode, improve the utilization efficiency of power distribution equipment and other aspects to provide support to further improve the efficiency of power distribution automation. At the same time, through the decentralized construction of production control areas, real-time monitoring of the distribution network and equipment working conditions of each local electricity power company can be realized, which greatly reduces the workload of operators such as inspections and tests, and saves operating costs.

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