Design and Implementation of Real-time Power Grid WebGIS Visualization Framework Based on New Generation Dispatching and Control System

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Abstract—With the strengthening of the integrated characteristics of power grid and the construction of the New Generation Dispatching and Control System with "physical distribution, logical integration", the demand for global monitoring and analysis of power grid has gradually increased. On the basis of understanding of design of the new generation real-time dispatching and control data platform system, with the principles of componentization and servitization, the real-time power grid WebGIS visualization framework is designed and implemented. And this paper further introduces the design of the front-end secondary development interface and examples, as well as the cartographic generalization of the power grid WebGIS visual map. This framework has successfully supported the construction and online operation of several real-time power grid WebGIS visualization applications.

1. Introduction
With the expansion of the power grid, the improvement of safety operation standards and the development of various software and hardware technologies, the amount of power grid data and information increase rapidly, and the business becomes more complex. Dispatching agencies at or above the provincial level urgently need to obtain external environment information and real-time operation information of the power grid from "One Grid Diagram", so as to realize the overall monitoring and analysis of the power grid[1].

The development of real-time operation information of the power grid display can be divided into three stages: the first stage expresses real-time information in the form of tables and graphs, which pays attention to the description of local information, cannot express the overall trend and change area of the system, and cannot meet the analytical, suggestive needs of the power grid. The second stage is based on computer graphics technology, using vivid visualization graphics to display power grid operation information, providing dispatchers with an intuitive and reliable grid operation information monitoring interface, which improves analysis, promptness and generality[2,4]. Grid resources’ spatial distribution characteristics are closely related to the geographical location of the equipment. The geographical distribution of the grid also reflects the spatial distribution characteristics of power grid benefits[5]. In the third stage, GIS-based visualize products appear, which have a better overall effect on power grid operation monitoring and analysis operations. At the same time, it can comprehensively
analyze and display power grid equipment information and external environmental weather information for decision-making by dispatchers.

According to the requirements of the "14th Five-Year Plan" of the State Grid Corporation of China, the follow-up development should reflect the times, regularity, and overall situation, to promote the high-quality development of the company and the power grid. As one of the important contents, the construction progress of the new generation of power grid dispatching and control system is steadily advancing. The grid resource data collected in the dispatching and control cloud includes model data, EMS measurement data, event data, and external environment data. It comes from the smart grid dispatching technical support system (D5000), production management system (PMS), and dispatching management system (OMS) and other systems [6]. The real-time dispatching and control data platform, as the key system for the model and data interaction of the new generation system, is the main physical support for the data collection and processing of the entire network. It provides stable and reliable services for the new generation system, and real-time data services for various applications of power grid [7]. With the support of grid model data, real-time grid operation data and platform services, the development of real-time grid WebGIS visualization application has the required data conditions, network conditions and application scenarios.

2. Overall Design

During the design of the real-time power grid WebGIS visualization framework of the new generation dispatching and control system, the system design and deployment structure of the new generation real-time dispatching and control data platform are first studied, and the data sources and data matching relationships in the platform are studied. Combined with the requirements of the real-time power grid WebGIS visualization, the real-time power grid WebGIS visualization framework was designed, and the specific content of the framework service and componentization was proposed. Combined with the cartographic generalization, the map design of the power grid map overlaying with external weather information and real-time operation information was studied.

2.1. System Design of The Real-Time Data Platform

The real-time data platform realizes real-time data collection for the whole network, and realizes real-time data unified service based on object ID, and realizes fast parallel processing and calculation of data, including the raw data of the plant and stations and the whole network state estimation processing calculation [8]. So as to support the global analysis and display of real-time grid and other business scenarios in the new generation dispatching and control system, and provide real-time data subscription services such as "real-time data section" and "state estimation section".

The real-time data platform is designed according to the overall architecture of the dispatching and control cloud, and adopts national branch and provincial secondary deployment. Leading nodes deploy model data of main network with 220kV and above voltage and realize corresponding real-time data collection and processing, which focus on supporting the real-time business of the main network of the national and provincial dispatching agencies. Collaborative nodes deploy provincial network model data 35kV and above voltage and realize corresponding real-time data collection and processing, which focus on supporting real-time business of local power grids in provinces and counties [8]. The two-level nodes deploy real-time data unified services through the resource high-speed synchronous network to achieve real-time data sharing of different voltages. Real-time data of the entire network and full voltage levels can be obtained at the leading or collaborative node. The deployment architecture realizes the appropriate decoupling of different levels of business, and conforms to the technical route of business classification and data concentration.

The real-time data platform of different nodes is divided into two parts: production control area and non-production control area, as shown in Figure 1:
Fig.1. Partition architecture of new generation real-time data platform

The non-production control area can obtain the power grid model from the model data platform through the integrated data network and model data platform. The non-production control area synchronizes the power grid model to the production control area, and the production control area synchronizes the real-time and state estimation data section to the non-production control area. By using the technology of grid model online synchronization, digital object ID coding (referred to as "RT_ID") and real-time data unified service, the real-time data platform and the model data platform share a set of grid models. So we can easily correlate grid model and real-time operation information in various grid applications including real-time power grid visualization applications.

2.2. Analysis Of Application Requirements For the Real-Time Power Grid WebGIS Visualization

This paper analyzes the real-time power grid WebGIS visualization framework from two aspects: functional requirements and non-functional requirements. Functional requirements mainly include visualization of grid diagrams, external meteorological environment information, and real-time information of power grid operation; non-functional requirements analysis are mainly about the deployment scenario based on the new generation dispatching and control system.

Functional requirements analysis:
A. Support the publishing of Web Map Tile Service (WMTS) and the display of tile maps, and support the switching between administrative maps, custom styled maps, and satellite maps, as the overall scene base map display;
B. Support the publication of Web Feature Service (WFS) and the analysis of GeoJSON data, and the positioning and symbolic displaying of plants, lines, and towers of 35kV and above;
C. Support the generation and display of choropleth maps, interpolation maps, heat maps, and aggregate maps, and realize the conversion of point-distribution information of meteorological element monitoring into area-distribution display. Support superimposing and displaying high temperature, heavy rainfall, strong wind and other meteorological information on the grid map. Support the generation of typhoon, thermal power distribution, lightning distribution, icing and other meteorological warning thematic maps [9-10];
D. Support the display of visual elements such as arrows, bubbles and animated icons. The displaying style, color, width, and annotations are related to the data. Support to realize the display of real-time power flow, overrun, heavy load, power outage statistics and other operating information in the power grid [11].
E. Support the extension and overlay of third-party visualization plug-ins, including but not limited to ECharts, support bar graphs, pie charts and other statistical charts to display and expand visualization expressions for power grid operating information;

F. Support the display of temporal data, in the form of visualization in the form of dynamic display in the form of time axis and graphs, and assist in the analysis of the characteristics of the power grid operation status[12].

Deployment scenario analysis:
The real-time power grid WebGIS visualization applications are deployed in the non-production control area, as shown in Figure 2: different application scenarios may be distributed in different application centers, such as the external environment information of the grid displaying application is deployed in the analysis and decision center, and displaying "One Grid Diagram" in the man-machine cloud terminal, the Saas application service layer of the dispatching and control cloud provides GIS application of real-time power grid.

Fig.2. Real-time power grid WebGIS visualization application deployment scenario

Take Saas application service layer of the dispatching and control cloud as example, in accordance with the concept of "fat service and thin client", various application software provide users with multiple types of dispatch operation and management applications such as basic data retrieval and query, topic analysis and grid visualization, grid operation analysis and early warning, etc[7]. It is a common deployment scenario for real-time power grid WebGIS visualization applications. In order to avoid a set of application deployments with all the functions of the server and client, repeated function coverage between different applications, the server and the client should realize functional modularization, servitization and componentization to reduce the cost of update and maintenance.

3. Technical Route

3.1. Design Of Real-time Power Grid WebGIS Visualization Framework
Combine real-time power grid WebGIS functional requirements and deployment scenario analysis, and follow the principles of front-end and back-end separation, servicing and componentization, as shown in Figure3: the architecture of the real-time power grid WebGIS visualization framework adopts a layered approach, which includes data layer, service layer and presentation layer.
A. The data layer: based on the unified model of new generation dispatching and control and object ID coding, model data, operation data and real-time data are stored in the national and provincial nodes, and are interconnected and updated, and the equipment spatial information is stored in the plant station, line, tower and line-tower relationship tables[13]. External meteorological information is accessed from the meteorological system and stored in the operating data platform. The spatiotemporal information is stored in the records of the actual measurement and prediction points of various meteorological elements; the basic geographic vector and raster data are stored in the base map server in the form of files.

B. The service layer: based on of the new generation dispatching and control system, includes data services based on Dubbo service framework and RESTful application services. Data services based on the dubbo service framework are deployed in different nodes to obtain and publish power grid models of 220kV and above voltage and related operating information from the national branch node, and models and information of 35kV and above from provincial nodes. Based on the operating data platform to publish the dubbo service of weather measurement, forecast and weather data in station; to call the real-time data Dubbo service interface, and publish Restful services related to trend, over-limit, and state estimation that meet the requirements of application conditions; to combine model data, external weather data and power grid operation data with spatial analysis methods, as to provide spatial analysis Restful services. In order to meet the display of the base map, based on basic geographic vector and raster data, this layer realize the WMS services that comply with OGC specifications.

C. Presentation layer: combine the requirements of grid visualization scenarios to realize a front-end framework with secondary development interface, this layer mainly includes basic map function modules, grid model drawing and interaction modules, map visualization modules, and element avoidance and other algorithm modules. It is developed based on Html5, JavaScript and OpenLayers open source GIS library, and provide basic scenario components of the power grid, secondary development API and secondary development examples. Combined with typical application scenarios, it realize thematic map examples such as typhoon display and early warning, line load rate thematic map, and station voltage heat map.

3.2. Real-time Power Grid WebGIS Visualization Front-end Framework
Real-time power grid WebGIS visualization has different application scenarios and different topics. The visualization function mapped to the map display logic has certain similarities, and there are differences in style parameters, and highlighted content. Therefore, the front-end framework is required to provide basic components for power grid display and secondary development interface and
development examples. Then it can provide with flexible and referenceable developing methodology for power grid WebGIS application developers.

Combined with the grid visualization scenarios, and further customized development based on the OpenLayers library, the framework provides the following categories of interfaces: map interface, layer interface, style interface, control interface, thematic visualization interface, and spatial analysis interface, detailed information is shown in Figure 4:

Fig.4. secondary development interface of real-time power grid WebGIS visualization framework

At the same time, it provides secondary development examples of typical applications of the power grid WebGIS visualization. Each example implements the map with one specific thematic maps, and demonstrates the calling sequence and usage methods with the secondary development interfaces. As shown in Figure 5, the power grid WebGIS visualization secondary development examples mainly include the topics of basic map operations, custom layer visualization, meteorological information visualization, statistical information visualization.

Fig.5. Real-time power grid WebGIS visualization secondary development examples

Therefore, application developers can quickly verify the technical route of the basic functions of WebGIS visualization, and further adjust the input data source and output map style parameters according to the actual data characteristics, so that application developers can follow the customer’s requirements to develop the power grid WebGIS visualization application without understanding the complex GIS drawing principles.
3.3. Cartographic Generalization Of the Power Grid WebGIS Visual Map

The power grid WebGIS visualization map follows the GIS layer design idea[14], and the layer structure is shown in Figure 6:

A. Geographic base layer, mainly include administrative division types, remote sensing image types, and custom style geographic maps to express basic geographic elements;

B. Power grid network layer, the basic spatial information of power grid, includes power grid equipment such as plants (power plants, substations, converter stations, etc.), towers and lines with latitude and longitude. When the line has the connection relationship information of towers, its coordinate composition is that the start station connects the start tower to the end tower, and finally connects to the end station, otherwise, is that directly connected from the starting plant to the final plant or station;

C. External environment weather information layer, mainly includes conventional meteorological feature layers and thematic meteorological layers. Conventional meteorological layers include monitoring information of conventional meteorological elements such as temperature, rainfall, and humidity; thematic meteorological layers include special weather information such as typhoons, wildfires, and lightning;

D. Power grid operation information layer, mainly includes the electricity information such as installed capacity and output of the power plant, power outage status, on or off cloud status, fault information of the plant and the line, as well as the node voltage, line flow, line load rate, etc.

The amount of power grid spatial data and information is large[15], and the layers often overlap, conflict, and show the data with different types and characteristics. So the problem of focusing on is not clear always happening. Therefore, it is necessary to combine the data distribution law, importance, and data density to set the display content of layers in different scales and different interactive scenes, and also need to adjust the display symbols. Symbol information includes elements and annotation styles, specifications, colors, etc., so as to provide users with maps with prominent points, coordinated colors, symbol images, and beautiful maps.

4. RESULTS

The power grid WebGIS visualization framework in this paper has been used in the external weather environment typhoon large screen system of the East China Power Grid and the East China Real-time Power Grid System. The map of the typhoon large screen display system is shown in figure 7.
Fig. 7. External weather environment typhoon large screen system of the East China Power Grid

By providing the real-time and prediction typhoon path drawing interface and the overlay analysis interface, the dynamic display of the real-time typhoon path is realized, and the latest affected plants and lines and others are distinguished by the opacity of their styles to prompt the plants and lines within the typhoon circle. At the same time, the real-time power flow information of the line and the real-time fault information of the equipment is also connected to system, which are respectively displayed with the animation and tables. So as to realize displaying the power grid real-time operation status under the current typhoon weather and assist dispatchers to make predictions and warnings.

As shown in Figure 8, the framework is used in East China Real-time Power Grid System. The framework provides the implementation of front-end and back-end deployment of the power grid network display, and provides the bubble visualization development interface. The real-time grid system main page called these interface to realize the display and interaction of the real-time operation data on the map.

Fig. 8. East China Real-time Power Grid System

5. Conclusion
Based on the analysis of the system structure of the real-time data platform in the new generation dispatching and control system, this paper puts forward the design and technical route of the real-time power grid WebGIS visualization framework, with the design principles of componentization and servitization. The visualization development framework, power grid spatial information server, front-end application secondary development interface and application examples are implemented. The framework provides a set of relatively flexible power grid GIS visualization application customization methods to meet the display requirements of external information and real-time operating information. In practical applications, it supports the comprehensive analysis of external weather information such as typhoons and the power grid, and the visualization of power grid operation information such as power flow and over-limit information.
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