Volume 10 Issue 1, 2024
DOI: 10.6919/ICJE.202401_10(1).0025

Application of One Map Display Technology for Power Grid based on Regulation Cloud

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Abstract

The one-map of power grid adopts the full-network model of the control cloud platform as the basis for graphical display and interaction. In response to issues such as the limited style and flexibility of the graphical display content of the existing grid dispatch control system, and the insufficient visualization of the grid operating status, a one-map of power grid display technology based on the control cloud is proposed. This technology can display the grid operating status under different conditions, achieve historical scene reconstruction, real-time status monitoring, and future mode analysis of the grid, and thereby provide users with various business scenarios based on graphical display. This technology has been deployed and officially launched in the Provincial and above grid dispatch control centers III area in multiple regions, meeting the demand for displaying various business scenarios graphically and enhancing the comprehensive control capability of the control center for the grid operating status.

Keywords

Control Cloud; One Map of Power Grid; Comprehensive Control.

1. Introduction

With the development of the grid, the importance of grid graphics in the grid dispatch control system is increasingly prominent, and a set of grid graphic application services support is needed for the visualization and sharing of models [1]. Using graphics to describe the power system, the grid's interconnections, various power business scenarios can be displayed on one map, and the elements can be directly edited on the web interface to operate power system equipment, overlay various outputs of power system calculation and analysis modules, making the results clearer and easier to read. Therefore, the development of graphic applications has become a focus of attention in power application software [2]. The traditional regulation system graphics are stored in CIM/G format, effectively avoiding various problems caused by inconsistent formats when the grid graphics circulate between I and III areas [3,4], providing strong support for grid operation and management, but there are still shortcomings in its application at various levels of control centers:

(1) The current III-area grid graphics mainly come from the system diagrams drawn in the I area, which are drawn late, have a single and inflexible content style, and are difficult to meet the display requirements of graphic applications [5,6];

(2) Various III-area graphic application services of control centers at all levels lead to different forms of grid graphics display and the information is not easily shared [7];

(3) The current control system's grid graphics are fragmented, making it difficult to grasp the overall topology of the grid and unable to comprehensively display various business scenarios and their interrelated impacts [8].

Addressing the above shortcomings, this paper proposes a one-map of power grid display technology based on the regulation and control cloud, detailing key technologies such as multi-temporal control of graphics, graphic visualization, and multi-business scenario display. The one-map of power grid utilizes the full network model of the regulation and control cloud, breaking away from the limitation where the grid graphics of the existing control system can only partially and limitedly display the grid topology and operating conditions under certain voltages, and thus unable to comprehensively control the grid operating status at different time periods. It constructs a single grid graphic based on the jurisdictional range of substations and line interrelationships in all levels of control centers from a macroscopic perspective, unifying the graphic display form, enriching the graphic application scenarios, and greatly enhancing the intuitiveness and sharing level of grid information. This forms the basis for realizing various business scenario displays and gradually extends layer by layer, ultimately achieving a one-map representation of the entire grid.

2. The Overall Framework

As shown in Fig. 1, the one-map of power grid display technology based on the regulation and control cloud relies on the provincial and national cloud platforms, which respectively gather the power grid model data of the control centers at the provincial, municipal, county, national, and divisional levels [9]. Through model state management, graphic-temporal division, etc., the one-map display achieves graphic temporal division, and then relies on graphic visualization to realize the reproduction of business scenarios. The power grid graphics are transmitted in real-time between the national cloud and provincial or municipal clouds through the scheduling data network, ultimately forming a complete macro power grid topology structure, highly unified with the model, globally shareable, and providing real-time feedback on power grid operation status.

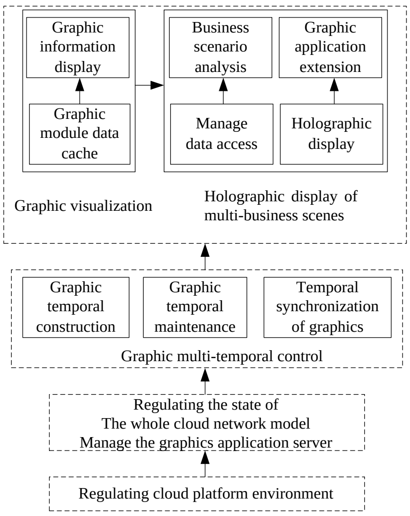

Fig. 1 Overall framework of one-map of power grid based on regulation and control cloud

The application of the one-map display of the power grid is based on the regulation and control cloud's network-wide model state information to establish unique temporal identifiers for different graphics, thus achieving integrated management and control of graphics and models [10], thereby realizing graphic temporal division.

The multi-temporal control of graphics realizes the construction, maintenance, and synchronization functions of the power grid graphics over different time frames. According to the model state, the graphics extract cross-sectional model data from the control cloud's network-wide model at a certain moment, and assign a unique identifier to each graphic time frame [11]. Maintenance personnel initiate the editing mode for graphic time frames, establish graphic maintenance tasks, draw graphics

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0025

uniformly in the browser, automatically correct the graphics, save the model change records and graphic change lines under the corresponding time frame.

The visualization of graphics interconnects graphic information through the processing of model data, generating different types of graphic elements based on the geographic information and interrelationships between models and creating graphic element logical layouts and interconnections. The spatial indexing mechanism of the non-relational database MongoDB is used to map the logical coordinates of the graphic elements, achieving rapid indexed layout of the graphic elements. Based on the graphic ID, the corresponding model data in the relational database is fetched to efficiently render and display the model data in the same time frame, fully displaying the current connection status of the power grid under the jurisdiction of the current dispatch institution. It also hierarchically displays different voltage levels and the stations and lines in different regions, comprehensively grasps the graphic display form, and overall controls the power grid topology structure.

Multi-service scenario display focuses on the modular graphical application display framework and business scenario analysis method based on graphical visualization components, which is highly extensible and universal [12,13]. The modular graphic application display framework and business scenario analysis method based on the visualization component effectively achieve multiple business scenario connections and reproduce the operational status of a specific section of the power grid. The business scenario analysis is based on the model and involves analyzing the connection relationships between graphic elements in the power grid graphics under different time frames, forming the process of visual application. The multiple business scenario displays enrich the graphic application scenarios, comprehensively displaying the power grid’s operational status, and macroscopically controlling the interrelated influences between various businesses.

3. Key Technologies

The display of the one-map of power grid is the result of the interaction among modules such as graphic application extension, business scenario analysis, graph model data display, and graphic temporal synchronization. The core technologies of the one-map of power grid include graphic multi-temporal control, graphic visualization, and diversified business scenario display.

3.1 Graphic Multi-temporal Control

3.1.1 Graphic Temporal Construction

In the control cloud platform environment, different temporal graphic data is divided based on the model state to create model temporal labels. By using the current model data as the base, unique temporal identifiers are created for graphics based on model temporal labels, and the model state determination criteria are established. The grid section data is extracted through model state determination to generate a basic graphic and assign temporal identifiers, forming different temporal graphics.

During the construction of the graphic temporality, different temporality collections correspond to the future, planning, and operation of the power grid, each having a change record. Updates are iteratively made to the basic graphics of each temporal collection, evolving the state changes of the power grid. After the graphic temporality construction, the graphic change records of the different temporal graphic sets are traced, providing the ability to retrace the different stages of the power grid's evolution. On saving the graphics, the graph model data is written into a relational database and archived.

3.1.2 Graphic Temporal Maintenance

In the graphic temporal maintenance environment, graphic editing is initiated by specifying the temporal context, creating branched differential graphic maintenance tasks, and controlling graphic model changes in a task-oriented manner, providing isolated data read-write environments for concurrent maintenance of multi-temporal graphics [14]. Graphic model maintenance uses the relational database as a storage medium and adopts a structured approach to update graphic model

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DOI: 10.6919/ICJE.202401_10(1).0025

data. Maintenance is carried out through a browser in an integrated manner for the graphics and models in the corresponding temporal maintenance environment.

When manipulating graphic elements in the browser, model change information is synchronized, and upon completion of maintenance tasks, unified model changes and graphic drawing are carried out, achieving unified model maintenance. In the unified temporal graphic maintenance environment, the editing and preservation of graphics are synchronized through task locks and differential comparison to prevent conflicts in graphic model updates [15]. Only after the current graphics have been reviewed and published can the next phase of maintenance tasks be initiated to ensure consistency between model change records and graphic change lines.

3.1.3 Graphic Temporal Synchronization

Graphic temporal synchronization can be divided into two phases: graphic model synchronization and graphic model changes. In the graphic model synchronization phase, different temporal graphic data is extracted based on the ledger equipment model, and planning data and new investment and retirement data are imported separately into future and planning temporal states to synchronize the graphic model, resulting in future, and planning temporal graphics. In the graphic model change phase, the layout of the future temporal graphics is referenced for the planning temporal changes in the graphic model, altering the graphic layout to conform to the planning layout in the future state, thereby obtaining planning temporal graphics through maintenance. Upon the review and publication of the planning temporal graphics, equipment status changes trigger ledger changes, leading to changes in the operational state graphics. After referencing the layout of the planning state graphics, the graphic model information is altered, audited, and published, and the archived graphics reflect this process.

Based on the transformation rules of the graphic model between different temporal states, the graph temporal transforms data of the graphic model in different temporal states, realizing the mutual sharing of graphic information that was originally isolated from each other. This avoids the additional work of repeatedly drawing graphics, provides a channel for the mutual evolution of graphics between different temporal states, and provides a basis for planning judgment for the future-to-operation transition of the power grid graphics.

Real-time control of the entire process of power grid graphics from the future state, planning state to operational state, records the entire process of changes in power grid operation status and realizes full-process management of network equipment changes. It meets the requirements of graphic applications and is the foundation of the display of one map of power grid.

3.2 Graphic Visualization

Traditional control systems often use XML-based SVG graphic formats for power grid graphic display. It has the characteristics of high image quality, small graphic size, easy storage, and strong scalability. The file format also has standard specifications, making it convenient for interaction and conversion [16, 17]. However, when there are too many elements in SVG graphics, problems such as slow graphic loading, inconvenient graphic element operation, and lag in dynamic rendering can occur, which is not conducive to graphic maintenance and application extension through the browser. Therefore, it is necessary to cache the graphics to improve its rendering capability and application effects. MongoDB, as a typical representative of a non-relational database, does not require fixed table structure, has flexible data storage, and has the advantages of high concurrency and efficiency, as well as full indexing of large data volume, making it suitable for caching graphic model data. Therefore, using MongoDB as the medium for graphic caching, and pushing the cached data to the web front end in real-time through its spatial index mechanism effectively improves the rendering efficiency and scalability of graphics, and can export SVG power grid graphics for interaction according to the standard configuration of power system resources.

Graphic visualization [19] is the process in which a web browser triggers model data processing, graphic model data caching, and graphic information display for specified temporal state graphics. It presents the graphic model data in different temporal states to users, making it convenient for them

Volume 10 Issue 1, 2024
DOI: 10.6919/ICJE.202401_10(1).0025

to intuitively trace the power grid status at any moment, and provides powerful support for various business scenario displays. The graphic visualization process is shown in Fig. 2.

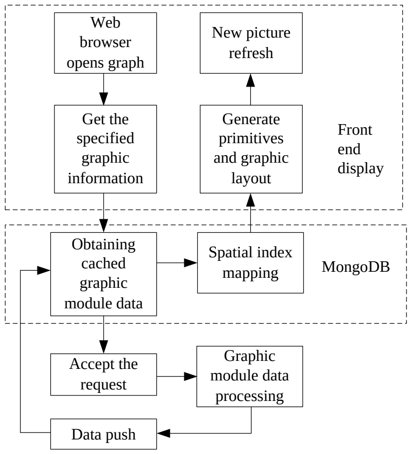

Fig. 2 The graphic visualization process

The web frontend retrieves temporal state graphics through a graphic index page, accesses the specified graphic, and queries the corresponding model data from the MongoDB cache based on its information. If there is no corresponding model data in the cache, a data request is sent to the backend. Upon receiving the request, the backend processes the model data and pushes it to MongoDB. When the same graphic is reopened, the data is retrieved directly from the cache without the need to request it from the backend. If corresponding model data exists in the cache, it is retrieved directly. After obtaining the model data, it is mapped to the frontend through MongoDB's spatial indexing mechanism, generating corresponding graphic element information and layout, refreshing the graphic display, and showing it.

3.3 Multi-business Scenario Display

The multi-business scenario display of the one-map of power grid enables the visualization of historical and future models, as well as the display of maintenance plans, fault contingency plans, section limits, and protection configurations in a graphical manner [20]. Trace the source of the graph through the graph release time stamp, and call the archived graph display in running state when inverting the historical scene; When monitoring the real-time state, calling the current graphical display of the running state.

Based on multi-temporal control and visualization of graphics, it can be displayed through the browser, which is beneficial to the superposition of various power grid information on the graphics. And because a map of the power grid comprehensively shows the connection and topological structure of the power grid from the overall macro perspective, the display level is deepened step by step, extending from the whole network to the provincial, prefecture and county networks, enriching the application scenarios of graphics.

When opening a graphic in the browser, the management data service access interface is called to retrieve management data related to the model ID from the model data for business scenario analysis. This forms the basis for specialized applications and extensions on the visual components of the graphic after model data processing and analysis.

Furthermore, based on real-time and historical data from the control cloud, the power grid whole-model is automatically mapped, and graphic layering and zoning management are overlaid with grid connection methods, operating modes, power flow distribution, comprehensive intelligent alarms, equipment fault and defect information, protection configuration information, and equipment maintenance information. This comprehensive approach caters to various professional perspectives,

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0025

providing accurate and comprehensive foundational data and visual support, leading to the formation of application modules such as maintenance visualization, flow visualization, and fault visualization, showcasing the power grid’s real-time or historical section state and operational methods. The one-map of power grid effectively supports the visualization of various power grid business scenarios.

4. Experimental Verification

In traditional control systems, the style of the one-map power grid is single, only displaying the topological structure of the power grid for a limited voltage level, and presenting partial power grid interconnection information. It is unable to provide a macroscopic understanding of the entire power grid’s structure and operational status. Additionally, it suffers from the limitation of only being able to display a single application scenario, making it difficult to meet the needs of various business scenarios such as power flow, maintenance, and fault management.

Compared to traditional power grid graphics, the one map of power grid achieves temporal control based on the control cloud. Its graphic elements have diverse styles, and the graphic information can be dynamically loaded, allowing for customizable display styles and rich presentation formats. It can quickly render and display in complex areas of the power grid structure, solving the problem of delayed real-time feedback in traditional power grid graphics in III area, effectively monitoring the operational status of the power grid. Through the one map of power grid, each control center can create its own distinctive power grid graphics and meet its specific management needs for various scenarios, achieving comprehensive display of various business scenarios. The comparison results of the one map of power grid display technology with traditional methods are shown in Table 1.

Table 1. The comparison results of the one map of power grid display technology with traditional methods

Comparison term	One map of power grid	Traditional methods
Whether to support multi-dimensional display of graphics?	Yes	No
Whether to support the interconnection of various graphic application scenarios?	Yes	No
Whether to support temporal control of graphics based on regulatory cloud?	Yes	No
Whether to support rapid rendering and display of complex power grid graphics?	Yes	No
Whether to support the interconnection of graphic information and can be accessed remotely in different regions?	Yes	No

5. Application Examples

The one map of power grid display technology based on the control cloud proposed in this paper has been successfully applied in multiple control centers and can be accessed directly through a web browser. The one map of power grid generates power grid graphics at national, regional, provincial, divisional, and county levels, which can be edited and maintained in the web interface. It utilizes the associated relationships with existing models to synchronize and update model data, establishing a two-level data synchronization mechanism between national, regional, and provincial control centers, and achieving model sharing as well as hierarchical zoning maintenance based on the scheduling level.

The one map of power grid overlays various power grid information, showcasing multiple business scenarios, and provides a macroscopic understanding of the structure and status of the power grid within the jurisdiction of control centers at all levels, thereby achieving the goal of visualizing various power grid information.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202401_10(1).0025

6. Conclusion

The application results demonstrate that the one map of power grid display technology based on the control cloud proposed in this paper explores an integrated graphical model with multi-temporal control mechanisms at the national, provincial, municipal, and county levels. The graphical representation at each level is harmoniously connected, achieving a vertically expandable and horizontally extendable one map of power grid, unifying the display format of the control centers at all levels and facilitating information sharing. Through the graphical temporal maintenance synchronization, the model can be timely maintained from the source end for future, planning, and operational states. By using the control cloud’s network-wide topology and power grid section data, the development of the one map of power grid application has enriched the graphical display content and styles, greatly satisfying the need for showcasing various business scenarios in the III area. The one map of power grid comprehensively and fully displays the power grid's connection and operation methods, effectively promoting the level of power grid graphical visualization demonstration and significantly enhancing the control center's overall control capability over the power grid operation status.

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