Digital Power Grid Construction Research of the Cross-regional Core Power Transmission Grid in Southwest China Based on Ubiquitous electric Internet of Things

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Abstract. Digital power grid, as an important foundation for building a strong smart grid, provides the unified data management and service application by integrating multi-source data such as fundamental geography, geologic physiognomy, power grid subjects and projects. It has become an important branch of the "Ubiquitous electric Internet of Things" (UeIoT) construction. Southwest China with a vast territory, has complex terrain and geology conditions. With the orderly advance of the construction of the Ultra High Voltage (UHV) main grid in the area, the power grid data assets have been gradually accumulated. Thus it is necessary to build a digital power grid to solve the difficulty in power grid construction and data asset management. Based on the construction idea of UeIoT, this paper proposes a set of technical architecture for the digital power grid construction of the cross-regional core power transmission grid in Southwest China, and introduces the ideas and application schemes of the digital power grid platform construction.

1. Introduction

Since the 1990s, the digital technology, characterized by integration, networking and intelligence, has been developed rapidly, which provides inspiration for solving the challenges faced by the contemporary power grid [1]. Scholars and experts at home and abroad have put forward some ideas for the future power grid development. The first one is "Digital Power System (DPS)" concept [2] proposed by Tsinghua University in 1999. Then, in 2003, American Electric Power Research Institute (EPRI) defined the future grid as "IntelliGrid"[3]. In the same year, the US Department of Energy (DOE) proposed the GRID2030 plan [4]; in 2005, based on European technology platform (ETP), Europe put forward the concept of "Smart Grid"[5]. In recent years, some regional, provincial and municipal power companies in China have also developed the idea of digital power grid. As a typical example, Shanghai Electric Power Company has put forward the concept of "digital power supply system", which expresses that the connotation of digital power supply system is "digitalization of power grid monitoring, informatization of business processing and integration of management and decision-making"[6].

In 2019, the State Grid Corporation of China (SGCC) proposed the construction of a ubiquitous electric Internet of Things, fully applying the modern information technology and advanced communication technology such as mobile interconnection, artificial intelligence and so on, realizing...
the Internet of Everything and human-computer interaction in all links of the power system, constructing a UeIoT with comprehensive state perception, efficient information processing, and convenient and flexible application, and providing powerful data resource support for safe and economic operation of the power grid, the improvement of operation performance and service quality, the development of emerging industries of strategic importance [7]. The SGCC has positioned the construction of the Ubiquitous electric Internet of Things as an important component of building a world-class energy Internet.

The International Standardization Organization /International Electro technical Commission (ISO/IEC) defines the Internet of Things as “An infrastructure that interconnects objects, people, systems, and information resources, combined with intelligent services that enable it to process and respond to information in the physical and virtual worlds [8]. The ubiquitous power Internet of Things is essentially an Internet of Things, a specific manifestation and application of ubiquitous IoT in the power industry. [9]. Digital power grid, as an important direction of the UeIoT, comprehensively uses various advanced technologies and digital means to accurately digitally describe the information and data on the actual physical power grid by integrating multi-source data such as the fundamental geography, geologic physiognomy, power grid subjects and projects, and provide unified data management and service application. This change to the digital representation is a new revolution in the traditional concept of power grid management [10]. Meanwhile, in order to meet the needs of national economy and social progress, digital power grid technology is developing towards high voltage, large capacity, cross-regional and large power grids [11, 12]. Especially, the terrain and geological conditions of Southwest China are complex with the precipitous mountainous areas, where the power grid project is facing the difficult construction and heavy management of planning, construction, operation and maintenance. Since the establishment of the Southwest Branch of State Grid, the Southwest main grid construction has been continuously promoted, and the accumulation of cross-regional power grid data assets has become richer. In order to mine the value of data assets, it is necessary to construct the inner-regional digital power grid to solve the outstanding contradictions.

2. Overall technical architecture

As other IoT systems, the Ubiquitous electric Internet of Things architecture is divided into four layers: perception layer, network layer, platform layer and application layer. The platform layer is the core of the whole IoT system. Generally speaking, with the platform layer as the boundary, the direction from the top to the application layer is called the north direction, and the direction down to the perception layer is the south direction, so the platform layer will be called the medium platform [7]. Combined with the digital power grid construction of the Southwest inner-regional core power transmission projects, its four levels are as follows: (1) Perception layer, which mainly includes the Southwest cross-regional core power transmission grid body, line operation sensing monitoring hardware and related multi-service data storage terminal; (2) Network layer, mainly including power fiber transmission for power grid sensing and data access, mobile 4G/5G transmission, satellite transmission of communication layers and network infrastructure; (3) Platform layer, mainly including digital power grid platform based on GIS platform, including power grid assets data center, monitoring and management center, etc. (4) Application layer, mainly including data assets visualization, geological hazards warning monitoring, power grid operation safety monitoring, external comprehensive data service, etc.
3. Construction of platform layer for Digital Power Grid

3.1. Power grid data asset integration

Grid data resources are generated in all aspects of planning, design, construction, production, maintenance, and emergency. The data types, data structures and management modes are complex and diverse. On the basis of data integration technology, implementing hierarchical organization and classification management for all kinds of data, and building a centralized and unified power resource database, are conducive to subsequent digital grid database construction and data sharing access.

Data integration process includes data collection and organization, data processing, database construction. The overall technical process is shown in figure 2. (1) Data collection and organization. The system has integrated various types of data, including: basic geographic data, power thematic data, grid data, three-dimensional models, file data, external transmission channel data, external interface data (geological hazard monitoring, regional real-time weather, dispatching monitoring data, etc.). (2) Data processing. The system filtered the inconsistent, missing, abnormal and redundant data. For vector data, merging similar layers, standardizing layer names, and giving attribute information of graphics object can make data association query on map. For raster data, the raster data in picture format was converted into vector data by geographic registration, coordinate transformation, vectorization and so on. For digital elevation model (DEM) data, 3D terrain scene data was rendered and generated by coordinate correction and other operations. For 3D model, the model data transferred in design phase was enforced format conversion and optimization. (3) Database construction. For these multi-source data, the system adopted heterogeneous database to classify and store the data. For basic geographic data and thematic data, tile data was generated by image pyramid and stored in local server. Xml was used to record its storage location. And spatial three-dimensional engine is used to realize its management and display. For the three-dimensional model data and transmission line data, the relational database was adopted. According to established data table, data dictionary and mapping relation, the data was matched into the database. For the engineering file data, the file server was used to store the location, category and other information in the Access database, which has been managed and displayed according to the structure of the storage folder level directory.
3.2. Multi-source data interface construction

The external interface data is a topic-oriented, integrated, current detail data set that supports the platform's real-time monitoring and real-time business needs. The acquisition methods include Extract-Transform-Load (ETL) and custom development data management tools.

Geospatial data from different GIS thematic application system shows multi-space and multi-scale, and data storage formats and structure differences are obvious, making the problem of sharing and integration of geospatial data increasingly prominent. ETL is a process of data extraction, transformation, and loading. It is responsible for extracting data from decentralized and heterogeneous data sources, such as relational data and flat data files, into a temporary intermediate layer, cleaning, converting, integrating, and finally loading into the data warehouse or data marts, and the data warehouse is built to meet the needs of most legacy heterogeneous systems, applications, and data source applications to achieve "data centralization, business integration, management flat, decision-making Scientific purpose" [13].

At the same time, in order to meet the increasing information search requirements of users, Python-based data crawling technology was applied to quickly search for web-based service data. The platform layer used the webpage downloader to crawl the page content according to the pre-designed URL, filter the source code for different filtering requirements, obtain the information required by the system, and store it in the local. Python-based data crawling technology periodically captured webpage information through the update time set by the system. Compared with the traditional browser information search mode, it had higher accuracy and more information, and could effectively solve the problem of the information accumulation caused by a large number of source code generated by rewriting, and effectively improved the utilization of resource space. The two interface designs are shown in Figure 3.
3.3. Platform construction

The digital foundation platform of power grid engineering is the foundation of digital power grid construction. The construction of digital power grid foundation platform can be used to effectively manage power grid engineering data, classify, query and count data, provide data support for other business systems, realize data sharing, and establish “virtual power grid” by 3D visualization technology. Platform construction mainly includes platform construction content analysis, key technology analysis, and platform technology framework design, as shown in Figure 4.

(1) Analysis of platform construction content

From the necessary conditions for digital power grid construction, the work of platform construction includes: software and hardware architecture deployment, geographic information platform selection, and visual display platform construction. In the system, the hardware architecture was divided into servers, network switches, network firewalls and clients, which are the guarantee for construction, normal operation and use of the system. The client implemented the interaction between the user and the back-end server, the network switch was responsible for forwarding the network request, the network firewall ensured the security of the network access, and the primary server was used to store data and process the client's request. For the geographic information platform, the 3D geographic information platform that meets the requirements of the power industry was chose as the 3D technology framework. The platform had a strong underlying development technology and multi-format data support. It could be customized according to user requirements, and publish data in a data bus manner. Digital grid visual display platform, through the previous operations such as basic geographic data processing, grid data modeling, engineering data storage, etc., was used to display the 2D or 3D power grid model, and
improved basic data support and platform support for design, construction, operation and maintenance, etc.

(2) Analysis of key techniques

Key techniques for platform construction included: big data acquisition, storage and management techniques, and 3D geographic information system techniques. Aiming at the massive multi-source data, based on the spatial quad-tree principle, the pyramid model of spatial data was constructed, the fast indexing mechanism of each type of spatial data was established, the database was used to store data, and the spatial index was used to realize the rapid scheduling of spatial data. 3D GIS technology could collect, store, manage, calculate, analyze and display three-dimensional geographic data in whole or part of the Earth's surface space with the support of computer software and hardware systems. It had data organization, data analysis and 3D performance, and was the basic support of 3D virtual systems.

(3) Platform technique framework design

The platform technique framework involved the data architecture layer, the technique architecture layer, the business architecture layer, and the performance architecture layer. The data architecture layer was the basis for supporting professional application services. It was responsible for managing various basic data of digital power grids, thematic data and engineering data, and providing unified data access services to the business layer. The technical architecture layer was based on software, hardware and network support, and was supported by key techniques such as geographic information system, 3D digital modeling and digital collaborative design; the business architecture layer centrally and intuitively reflected the application functions of the platform, providing the business functions such as three-dimensional visualization, data asset application, data management and decision analysis; the performance architecture layer constructed the interface of human-computer interaction platform for the power grid data asset visualization with a better user experience.

4. Digital power grid application layer construction

4.1. Power grid data asset visualization management

The platform covered various real power grid assets, space geographic information, and three-dimensional digital results in planning, design, construction and operation, as well as intelligent dispatching of power grid, real-time synchronous data collection and many other contents. Supported by 3D geographic information technology, multi-source information system integration technology and whole-process information power grid technology, under the unified framework, the full-information three-dimensional visual simulation for power grid data assets visually displayed the geographical distribution, channel overview, disaster monitoring, dispatching operation and various power grid thematic data of the power system. Through the combination of two-dimensional elements and three-dimensional digital models, the spatial position and local details of the transmission line and substation were accurately positioned and simulated, and the scene was reproduced in the three-dimensional map (as shown in Figure 5).
At the same time, based on the three-dimensional model, the relationship between the model and each isolated information was established to realize information connectivity. The platform took the tower model as the axis, accessed the production management information and electronic design files to realize the management and query of engineering information and design parameters (as shown in Figure 6), and accessed real-time information such as online monitoring and scheduling to fully exploit the potential value of diverse information. Through the establishment of the association relationship, the user can easily query all the information related to the model by clicking the power model, thereby realizing the integration of the power information centered on the space model.

Figure 5. Engineering 2/3-D visualization.

Figure 6. Engineering equipment file inquiry.
4.2. **Auxiliary Power Grid Channel Management and Decision**

The platform restored and reproduced the channels in a graphical and visual way, which showed the channel planning constraints and results to assist in the channel route selection and site selection. After the completion of the planning scheme, the channel scheme information could be synchronized to the three-dimensional virtual space, simulate the scene environment, and display the real environment and expected results of the power grid and the planning channel. By superimposing the planning results and the thematic data, multi-angle observation, analysis of the relationship between terrain, environmentally sensitive areas and route paths (as shown in Figure 7), and comparison with the planned Ultra-high voltage transmission line to visually determine whether the corridor path is reasonable. This 2/3D synchronization method can assist in program comparison analysis and program review.

![Figure 7. Transmission channel scheme display.](image)

4.3. **Auxiliary geological disaster monitoring and warning**

The platform accessed various geological disaster risk assessment data and evaluation result data (as shown in Figure 8). Based on this, suspected geological disaster areas were realized a wide range of rapid screening. What’s more, the platform combined online monitoring equipment for transmission lines to access online monitoring signals, and construct monitoring warning indicators and models for geological disasters. It could effectively assist disaster monitoring visualization, improve the acquisition efficiency of disaster information, and the scientific decision-making in the development of power grids.
4.4. Auxiliary power grid safety monitoring

The access to transmission status monitoring, numerical weather prediction and other data for overall management, including the design, construction, operation and maintenance information of the power grid to provide a unified data access service, in the form of digital archives to quickly organize the design parameters, drawing files and monitoring information along the transmission line, such as the temperature, humidity, ice, pollution, wire dancing, video, etc., integrating the professional system data such as lightning, ice, wind, fire, etc., could assist to information collection, process management, warning research and coordination (as shown in Figure 9).

5. Conclusion

Based on the application of the Ubiquitous electric Internet of Things, this paper proposes a digital power grid construction technology by studying the data asset management and 3D visualization of the Southwest cross-regional core power transmission grid from data asset integration, database
construction, platform construction and application services. The related technical solution for digital power grid construction, shares and integrates the data dispersed in each business management system, and fuses the space visualization and business data, which can provide decision support for power grid operation management. With the development of technologies such as artificial intelligence, Internet of Things, big data, cloud computing and other technologies, how to aggregate existing business system data, take the power grid business as the core, and deeply mine the effective data in all links to achieve integrated application, comprehensive analysis, and full-scale visible digital power grid, and provide intelligent assistant decision-making for power grid management, will be an important direction for future research.

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