Construction and application research of Three-dimensional digital power grid in Southwest China

Yang Zhou 1,*, Hong Zhou 2, Chuan You 2, Li Jiang 2, Weidong Xin 1

1Beijing North-Star Remote Sensing Technology Co., Ltd, Beijing 100120, China.
2South-West Branch of State Grid, Cheng Du 610000, China;

*Corresponding author e-mail:zhouyang@eppei.com

Abstract. With the rapid development of Three-dimensional (3D) digital design technology in the field of power grid construction, the data foundation and technical means of 3D digital power grid construction approaches perfection. 3D digital power grid has gradually developed into an important part of power grid construction and management. In view of the complicated geological conditions in Southwest China and the difficulty in power grid construction and management, this paper is based on the data assets of Southwest power grid, and it aims at establishing a 3D digital power grid in Southwest China to provide effective support for power grid construction and operation management. This paper discusses the data architecture, technical architecture and system design and implementation process of the 3D digital power grid construction through teasing the key technology of 3D digital power grid. The application of power grid data assets management, transmission line corridor planning, geological hazards risk assessment, environmental impact assessment in 3D digital power grid are also discussed and analysed.

Key words. Southwest China; Three-dimensional digital power grid; Power grid data assets; Transmission line corridor planning.

1. Introduction
Southwest China with a vast territory has extremely complex terrain and geology conditions. The Hengduan Mountains adjacent to the Lancang River, the Nujiang River, the Yalu Tsangpo River and other well-known great rivers in Asia are the most complex, steepest and hugest mountain ridges. It is difficult to plan, construct and operate the power grid projects due to the adverse circumstances in this area. Therefore, it is of great application prospect to assist the construction and management of power grid with 3D visualization.

Data is one of the core vitality of information construction and management. The digital power grid can provide unified data management and service application by integrating multi-source data (e.g., the fundamental geography, geologic physiognomy, power grid subjects and projects). The development of digital power grid is largely constrained by the establishment of data channels. With the rapid development of the 3D digital design technology in the field of power grid projects, it spreads gradually from the level of design to the level of 3D digitization. Meanwhile, the State Grid Corporation of China (SGCC) releases the technical guidelines of the Ultra High Voltage (UHV) power transmission projects
digital handover technology, and it has gradually generalized and applied the 3D digital handover technology in the construction of every voltage grade of the power grid projects from high to low. The 3D digital handover work starts with the whole processes (i.e., planning, design, construction and completion) of power grid construction, and considers from a global perspective. It will lay a firm data base for the construction of the 3D digital power grid [1].

The inter-regional construction of power grid in the Southwest China develops for many years with the orderly advance of the construction of the UHV main grid in this area. It has accumulated abundant grid data assets. The demand of carrying out data assets integration management and data mining and integration application is increasingly strong in combination with the typical geological characteristics and environmental characteristics of the Southwest China. By means of the 3D geographic information system (GIS), large data and other technical means, constructing a unified 3D digital power grid in Southwest China to realize the rapid handover, centralized management and panorama of the design of the whole domain power grid projects. It provides effective support for power grid projects construction and operation management of power grid data assets management, transmission line corridor planning, hazards risk assessment and environmental impact analysis for Southwest China.

2. Methodology
The 3D digital power grid contains various actual power grid resources, power grid spatial geographic information, the power grid planning, the power grid design, it also contains the 3D digitization of various resources, the intelligent scheduling of the power grid, and the real-time synchronous data collection and any other information when the power grid is running [2,3]. We can easily grasp the geographical distribution of the power grid, the mode of operation and the power flow information, and we can also inspect the grid path, topography and geomorphology, the mountains and rivers, the railway and highway, the towns and many other thematic data through the 3D visualization simulation for the power grid information. The key technologies of 3D digital power grid contain the 3D GIS technology, the 3D digital design technology, the 3D digital handover technology and the multi-source mass data storage and management technology.

2.1. The 3D geographic information system technology
The 3D geographic is the carrier of establishing the 3D digital power grid. Its powerful ability of collection, management, analysis and exhibition lays a good foundation for 3D digital power grid. Through the high-resolution images and the high-precision terrain data collected by air photogrammetry, it can easily realize the macroscopic 3D visualization simulation of the transmission line [4]. It can easily build the GIM model for the power grid information which makes the constituent elements of the power grid digital through the model of power grid information and gathers all information in different stages. And it can easily construct the micro 3D display of power grid and make the information efficiently, accurately and comprehensively applied to be used at the same time.

2.2. The 3D digital design technology
The 3D digital design technology is the base of the 3D digital power grid. It is very clear that the realistic and up-to-date data is the basic requirement for building an availability 3D digital power grid. The design of the power grid should use the 3D technology and must hand over the required data to the follow-up stages in a timely manner. The 3D digital design technology is relied on the constructed 3D visualization engineering corridor environment. It is conducive to gather the information of the engineering corridor, design the line path, arrange the pole and tower, check the electrical clearance, and assemble the 3D insulator, the 3D tower and other basic configuration. The towers, insulators and other 3D elements of power grid which are built though the 3D digital design technology can visually and accurately reflect the design results of location layout, material type and direction size combining virtual reality and other technologies. The models can also make up the lack of traditional graphic design means effectively and play a very important role in improving the data acquisition effect, optimizing the design model and improving the quality of design as well [5-7].
2.3. **The 3D digital handover technology**

The 3D digital handover technology is the guarantee for the construction of 3D digital power grid, the establishment of 3D Power Grid System generally need at least real and effective terrain data, model data of power grid equipment, and associated design data, through deep processing of these data, produce the data for 3D digital power grid [3]. 3D digital handover technology refers to handover the overall packages of every stage of the power grid engineering which contains professional basic geographic data, design results data, thematic data and engineering archives. Through analyzing according to the specific organization rules, 3D digital power grid bearing platform is in accordance with agreed rules, then stores for unified management and application, from design to operation and maintenance of one-click delivery.

2.4. **The multi-source mass data storage and management technology**

The back-end of 3D digital power grid is a huge set of power grid data, the differences of data source and format are large, and the management and unified scheduling of multi-source mass grid data will become the key for the results of 3D digital power grid, it determines whether the 3D digital power grid can work efficiently. Multi-source data storage and management technology use spatial data engine and large relational database to build spatial database management system, eliminate multi-source heterogeneous data differences, and establish a rapid spatial index mechanism for each type of spatial data to achieve multi-source spatial data seamless integration and sharing management. Combined with data slicing and hierarchical processing to build pyramids, using the tile data mechanism and high-performance index to achieve massive geographic data access. It can provide a file management system for unstructured data for file transfer service, and combines with relational database to provide unstructured data metadata management and retrieval applications [8-10].

3. **Construction of the 3D digital power grid**

3.1. **Design of the overall framework**

For the multi-source and complexity of power grid data assets, and taking full consideration of the scalability and portability of system function construction, the 3D digital power grid system adopts three-tier C/S architecture to design the system. The overall structure is shown in Fig. 1.
Data layer
The data layer is the basis for supporting the professional application services. It is responsible for managing the basic data of the digital power grid, designing the special data and engineering data. At the same time, the data layer provides a unified data access service for the business layer. With the hierarchical organization and classification management of all kinds of data, it built a centralized, unified management of the power grid spatial database for the application of data access based on the spatial data engine and large database management system, which provides effective support for the access, management and sharing of data for all kinds of application services.

Business layer
The business layer can centralized and intuitively embodies the application functions of the platform. Based on the unified construction of the 3D GIS platform, classifying the logic of the data business, it is designed for the applicant and decision makers of the digital power grid, it provides the users with 3D visualization of the power grid, and the application of data assets (e.g. Auxiliary transmission line corridor planning, environmental sensitivity assessment and geological hazards risk assessment), data management and decision analysis and other auxiliary modules of the business functions to support the presentation layer dealing the business logic needs of all kinds of work.

Presentation layer
The presentation layer is responsible for the construction of the 3D digital power grid system human-computer interaction platform interface, focusing on providing users with a good user experience, it
contains a friendly user interface layout, checking and judgement of the basis of interactive logic, input and output interaction of system application modules, visualization of application analysis result of functions and so on.

3.2. Data access design
3D Digital power grid involves a wide varieties and large amount of data, and with the continuous increase of the data volume of the power grid projects, a reasonable set of data access and access architecture is essential to the data interaction application of the whole system. As is shown in Fig. 2. The data architecture design focuses on the storage and access management of all kinds of data, including various structured and unstructured data, which involve different categories of data, such as spatial data and attribute data.

![Power Grid Spatial Database](image)

**Fig. 2** Digital power grid multi-source data composition

In view of the various data resources of platform background data management, different access means should be applied to interact with each other, it focuses on the data layer design of the whole system architecture. The design emphasis of system data access depends on coordinating the data application requirements of the application layer and data layer of the data service demand, data classification based on equipment layer good storage management model, with convenient and fast way to provide all kinds of data access service, the data interaction design between the two is shown in Fig. 3.
For different data sources providing different data interaction access support, the external system is based on Web Service to encapsulate the corresponding service interface to provide data access support, 3D digital power grid internal encapsulates corresponding class library and provides data access support operation interface, data entity based on ADO.NET, NHibernate technologies, such as encapsulation structure business attribute data access interface, based on spatial data engine encapsulation of raster and vector format geographical spatial data access interface, based on OGC specifications packaging pyramid tiles map services such as data access interface, based on FTP encapsulation of unstructured document data access service. The internal and external interfaces jointly build data access and interaction support for 3D digital power grid platform.

3.3. System function design
According to the overall design and construction of the 3D digital power grid in the Southwest China, the functional structure of the platform system is shown in Fig. 4.
4. Application analysis of 3D digital power grid

4.1. Power grid data assets management

This paper established a 3D digital power grid of the Southwest China, based on 3D topography and 3D digital earth model. Using the macro earth and accurate 3D scenario, we present multiple-scale spatial distribution, geographical environment, engineering data and other information of the power grid project, which supports the rapid locating and fuzzy search of power equipment models (Fig. 5). Through establishing the connection of model information, design parameters, structural and non-structural drawings, the information of transmission and transformation project and equipment can be easily reached, which facilitate the management of project information, digitalization and visualization of power grid, and thus provide comprehensive and systematical data support for the maintenance and management of the power grid project.
4.2. **Auxiliary transmission line corridor planning**

The 3D digital power grid uses macroscopic corridor planning in the form of graphic visualization and realizes the restoration and panoramic representation of the corridor in the southwest region. It assists the planning of route selection, site selection and other corridor planning and layout work. It can show corridor planning constraints and results in the form of intuitionistic and vivid display to shorten the decision-making time and improve the efficiency of work. Through the overall layout of auxiliary transmission line corridor, fusion of multi-source data for statistical analysis, technology corridor and scheme choice, it can help to improve comprehensive technical and economic rationality of plan, and improve the depth and the lean level of planning; Using digital information system tools, the traditional multi-types, multiple formats of corridor data can be transformed into digital format and be layered management and provide digital data support for subsequent research, planning, designing, , which can also reduce the duplication of investment and improve the utilization rate of the data (Fig. 6).

![Fig. 5 3D Visualization of power grid data assets](image1)

![Fig. 6 Auxiliary transmission line corridor planning](image2)
4.3. **Auxiliary geological hazards risk assessment**

Various data which is unified managed by 3D digital power grid assist to carry out geological hazards risk assessment and damageable assessment, provide guidance for line or site selection in the early stage of power network engineering and later construction (Fig. 7). LiDAR data and high resolution DEM data based on long-term accumulation are applied to extract surface deformation, slope, shape and other indictors to achieve a wide range of rapid screening suspected area of geological hazards. According to the archives of geological survey data and images, we can verify and identify the important dangerous areas and potential hidden areas, understand the potential geological hazards distribution and disaster density indicators comprehensively. Combined with the transmission line on-line monitoring equipment, we can access to the online network monitoring signal to build geological hazards monitoring indicators and model to analyze the local key areas, a small range of geological stability conditions, development and evolution trends.

![Fig. 7 Results of geological hazards risk assessment (Green – low risk, Red – high risk)](image)

4.4. **Auxiliary environmental impact analysis**

According to the requirement of environmental sensitivity analysis in Southwest China’s transmission engineering, relying on rich and comprehensive terrain and topography, basic geography, soil geology, rainfall, multispectral image and environmental protection data, we can obtain a wide range of environment sensitive area information and extract slope index, vegetation index, vegetation productivity, landscape segmentation index, precipitation erosion and soil erosion index. The environmental impact analysis is carried out according to the evaluation model, and the ecological vulnerability within the regional scope is comprehensively evaluated. Through the archived data and environmental impact analysis results and providing a more friendly and intuitive way to assist transmission project environmental sensitivity assessment, we can avoid environmental fragile areas in the early project feasibility study, planning, construction process, reduce the destruction of environmental protection areas and the cost of power grid engineering, which is of great significance to enhance the safety and reliability of ours power grid project (Fig. 8).
Fig. 8 Results of environmental impact analysis (Green – low sensitivity, Red – high sensitivity, Blue – transmission line)

5. Conclusions and Prospections
This paper systematically introduces the key technologies of 3D digital power grid and the approaches of building the platform system with the goal of constructing 3D digital power grid in Southwest China, and explores its application in power grid project planning and construction, which can help improve the work efficiency, management level and decision-making level of power grid planning and construction, especially providing important support for the feasibility study, planning and maintenance management of power grid project in Southwest China. With the development of smart grid and the expansion of power grid scale, the types and quantities of power data are increasing rapidly. By means of large data, cloud computing and other latest technologies, through the aggregation of related business data, taking power grid business application as the core, deep mining the relationships between data in each link, so as to building a full dimensional visible digital power grid with integrated application and comprehensive analysis, improve staff control and decision-making ability of the power grid.

Acknowledgments
This research was supported by the Science and technology Project of SGCC Southwest China Branch. Corresponding author: Zhou Yang Telephone: 13611354105

References
[1] Wu ZhiLi, Han WenJun. Necessity and Urgency of Power Grid Project Digital Transfer Work [J]. Electric Power Construction, 2014, 02: 66-69.
[2] Jiang RongAn, Yan Ping. Application of 3D Digital the Electricity Network Technique in the Construction Management of Extra High Voltage Engineering [J]. Electric Power Survey & Design, 2007, 05: 65-68.
[3] Fan Guangfu, Zhu ZhongYao, Jiang RongAn. Solving Plan of 3D Digital Electric Network [J]. Electric Power Survey & Design, 2005, 01: 30-34.
[4] Zhao ZhiYu, Sun BeiNing, Li DongMei. Research on digital power grid application based on visualization technology [J]. China New Telecommunications, 2015, 23: 150-151.
[5] Guo XiPing. Research and development of three-dimensional digital and integrated information management platform of power grid [J]. Electric Power, 2013, 10: 96-100.
[6] You Chuan. Design and implementation of three-dimensional digital simulation system of transmission line [D]. University of Electronic Science and Technology of China, 2015.
[7] Ou XiaoYong, Li Xin, Chen JianBin. Research and application of 750kV digital power grid system [J]. Electric Power Information and Communication Technology, 2011, 10: 113-117.
[8] Wang YaGang. Design and implementation of the management system of digital design of power
grid engineering [D]. Fudan University, 2013.

[9] Zhou Liang, Cai Jun, Ding YiBo, Lv ZhengYu. Research on the three-dimensional digital management platform of transmission and transformation engineering based on IFC [J]. Power System and Clean Energy, 2015, 11:7-12.

[10] Zhang Jian, Zhang Hao, Jiang Jiong, Huang XiaoMing, Li MingLei. The construction and application of intelligent high voltage power transmission network management system based on three-dimensional geographic information technology [J]. Zhejiang Electric Power, 2015, 08:17-20+33.