Three-Dimensional Geographic Information System Assisted Intelligent Review of Power Grid Design

Yao Jin¹,², Xiaozhe Tan¹,², Linghou Miao¹,², Jie Zhao¹,², Zhuoyan Song¹,², Wuxing Yu¹,², Binglei Xue¹,², Dongliang Shao¹,²

¹Economic & Technology Research Institute of State Grid Shandong Electric Power Company, Jinan Shandong 250021, China, ²Shandong Zhiyuan Electric Power Design Consulting Co, Ltd, Jinan Shandong 250021, China

*Corresponding author e-mail: jinyao@jyy.sd.sgcc.com.cn

Abstract. In order to strengthen the management of the three-dimensional design review of power transmission and transformation projects, the Ministry of Infrastructure of the State Grid has successively issued the "Notice of Guiding Opinions on the Management of Preliminary Evaluation of Three-Dimensional Design of Transmission and Transformation Projects" and the "Preliminary Review Outline of Three-dimensional Design of Transmission and Transformation Projects (for Trial Implementation)" announcement. At present, most of the existing engineering design review systems are two-dimensional systems, which cannot visually display design results. In order to better display the results of three-dimensional design and improve review efficiency, it is necessary to apply GIS technology to the three-dimensional design of power transmission and transformation projects, and it is very necessary to develop a set of 3D GIS power transmission and transformation engineering design review system. In order to solve the above problems, the purpose of the present invention is to provide a method based on 3D GIS power transmission and transformation engineering design review, using 3D visualization technology to combine GIS with power transmission and transformation engineering design results to achieve visual browsing and query of 3D design models, and 3D design Achievement display, 3D design results review and scoring, 3D design model collision relationship calculation and other intelligent management applications.

Key words: 3D GIS, smart grid, grid design review.

1. Introduction
The research and application of the dimensional geographic information GIS system in the design review of power transmission and transformation projects takes data as the main line, and fully penetrates the design results data management platform of lines, power transformation, civil engineering and other projects, and manages the basic data and line rock of each design stage of the project. Information materials on soil, substation geotechnical, substation civil engineering and related engineering design results [1]. Realize the spatialization and 3D visualization management of data...
storage, inspection, editing, update, retrieval, etc. based on 3D GIS; establish the standardization of various data acquisition-submission-inspection-correction-reservation-application procedures, and formulate docking countries The unified data management standard of the relevant regulations of the Internet; through the data and design profession and the entire process of information collaboration and data extraction in the design stage; build a set of efficient three-dimensional display, empowering spatial information, keeping close to existing results, docking with other software, and breaking information An island, an intelligent data management review platform that realizes release and review.

The research and application of the construction of three-dimensional geographic information GIS system in the design review of power transmission and transformation projects will form a "rich mine" of data resources, which is the standard library of various data related to surveys by the Economic and Technical Research Institute of State Grid Shandong Electric Power Company. So as to better serve all design and operation and maintenance personnel in the institute, effectively improve work efficiency, and save engineering design operation and maintenance costs; it is also an important step in data standardization for the State Grid Shandong Electric Power Company Economic and Technical Research Institute, and the main focus of digital transformation; It is also the main gate of survey data and geographic information data of the Economic and Technical Research Institute of State Grid Shandong Electric Power Company, and the "source of living water" for data-related businesses.

2. Overall system design

2.1. Architecture design

The system technical architecture defines how to establish an IT physical environment to support the data and application architecture to ensure the normal operation of the application system. The technical architecture includes a software platform and a hardware platform. The software platform includes concepts such as software server and operating system, and is the software operating environment of the application system [2]. The hardware platform includes the physical facilities required for application deployment and communication such as hardware servers, workstations, networks, and mobile devices.

The system adopts a layered architecture design, each layer is relatively independent and loosely coupled, and communicates through a standard interface, which can improve the scalability of the system. Figure 1 shows the system architecture.
Figure 1. Three-dimensional geographic information GIS system architecture

The infrastructure layer is the existing hardware and network system, including servers, network links, routers, firewalls, etc., which constitute the basic operating environment of the system. The data layer includes design information database, review results database, business database, geographic information database, etc., which constitute the data foundation of the system. The service layer provides interfaces for data synchronization, data detection, data analysis, and data publishing for design data, business data, geographic data, etc., and provides functional interfaces for business realization for the application layer. The application layer provides corresponding operation interfaces according to business requirements, and provides tools for management and display work.

2.2. Business structure
The three-dimensional intelligent review platform for power grid engineering is based on the company’s power transmission and transformation project design review management system and three-dimensional design and handover standard specifications [3]. Through the review plan arrangement and review project distribution work, the three-dimensional design data is uniformly handed over and managed, and the new Three-dimensional technical means and methods realize the standardization of design results and realize the purpose of intelligent review management. Improve project data management capabilities as a whole, create an authoritative management model for three-dimensional design review of power transmission and transformation projects, and provide strong data support for the orderly development of project construction. The business architecture design is shown in Figure 2 below:
2.3. **Data Architecture**

Data architecture design includes required structured data and unstructured data. The structured data model (Data Model) is a scientific reflection of user information needs, a data description of objective things and their connections, and the information organization framework structure of the planning system. It is mainly divided into conceptual models, logical models, and physical models. Unstructured data includes indescribable data including documentation, GIS data, model data, etc. All data is stored in the database and server, and shared through DBA, GIS-Server, SFTP, etc., to facilitate the implementation of IT systems, thereby Carry out deeper integrated applications. The data structure of the review system is shown in Figure 3 below:

![Business Architecture Diagram](image)

**Figure 2.** Business architecture diagram

![Three-dimensional digital review data architecture diagram of power grid engineering](image)

**Figure 3.** Three-dimensional digital review data architecture diagram of power grid engineering
3. System function design

3.1. Three-dimensional roaming
Through three-dimensional roaming, the full picture of the substation is shown to the owner, which is convenient for the owner to judge whether the design fully meets the requirements. Let the owners have an understanding of the general planning, equipment layout, functions of each room in the main control building, and the greening of the area in the future substation, so that the owners have an intuitive and perceptual understanding of the completed substation [4]. For some electrical equipment that is large in appearance and difficult to transport, you can also simulate transportation and assembly from the three-dimensional design drawing, and observe the geographic location of the electrical equipment in the real three-dimensional space, reducing design errors and improving design accuracy.

3.2. Statistical analysis
Provide the owner with 3D model engineering data. Through the establishment of the substation database, the equipment parameters are stored in the equipment database, the graphics of various equipment are stored in the equipment graphic library, and the overall plane information, interval information and adopted equipment parameters of the substation are stored in the engineering database in a hierarchical manner. Accurately count materials, especially the length of pipes and cables, to achieve effective cost control.

3.3. Visualized construction process management
The current professional engineering management software platform has no interface with the design platform, and there is no connection between the construction progress and the three-dimensional model. Such construction management software does not have visibility and is not effective. Using the visualized three-dimensional browsing model, the query point of the three-dimensional browsing model synchronized with the design is set on the construction site for the design site service, construction personnel, operation, supervision, owner and other parties to browse at any time and guide the construction [5]. The project schedule, logistics and document management status can be adjusted at any time to adapt to the actual construction situation. The intelligent substation 3D design platform can be connected with various construction management platforms such as Primavera Project Planner (referred to as P3). By customizing the interface between the platforms, the process construction progress (i.e., time axis) of the construction management platform is imported to the three-dimensional animation roaming platform to form a four-dimensional substation engineering platform with visual construction management capabilities. According to the requirements of construction management, the plan and the actual progress of the project can be dynamically observed on the project model in real time, and the construction progress can be better controlled by comparing the plan with the actual project progress. The digital function of the model accurately extracts the material preparation list in time according to the project progress, ensuring the timely and accurate project material preparation, and effectively controlling the purchase cost.

4. Three-dimensional collaborative design process of power transmission and transformation engineering
The working environment of 3D design is based on an integrated working platform. Based on the above-mentioned analysis of the 3D collaborative power transmission and transformation engineering working mode, this paper uses data fusion and parallel working methods of different disciplines to implement references to upstream and downstream design results. Suppose HVAC, electrical, civil structures and buildings are random variables, X1, X2, X3, and X4, respectively, and use the weighted average method to fuse data from different disciplines. The form is:

\[ Y = kX_1 + (1-k)X_2 + (1-k)^2X_3 + (1-k)^3X_4 \]  \hspace{1cm} (1)
In the formula, Y represents the fusion operator of each parameter. The three-dimensional collaborative design process of power transmission and transformation project shown in Figure 4 is obtained.

![Diagram showing distributed computational engine and symbiosis theory](image)

**Figure 4.** Three-dimensional collaborative design process of power transmission and transformation engineering

Use the symbiosis theory to carry out the collaborative design of different management software, suppose that the symbiosis system S has a quality parameter X (S system capability), and includes m (m≥2) symbiosis units. In this paper, m=4, then there is:

\[ X_s = f(x_1, x_2, ..., x_m) \]  

(2)

The symbiosis degree of all elements of the system is

\[ \sigma_s = \frac{1}{\lambda} \sum_{i=1}^{m} \sigma_{si} \]  

(3)

In the formula: \( \sigma_{si} \) is the symbiosis degree of the unit elements in the system; \( \lambda \) is the symbiosis damping coefficient. The relationship between the system quality parameter \( X_S \) and the unit quality parameter \( X_i \) mainly depends on the symbiosis degree and characteristics of the symbiosis unit, including collaborative adaptation, interface trading, and complementary connection. Obtain the proportional relationship between the energy \( E_S \) of the three-dimensional collaborative digital system and the symbiosis degree of the system's total element \( \sigma_s \):

\[ E_s = f(\sigma_s) \]  

(4)

5. Experimental design
The experiment uses the method in this paper to analyze the construction quality of a certain power transmission and transformation project in a certain area, and conducts inspections on each
construction part of the power transmission and transformation project. The test results are described in Table 1. It can be clearly seen from the results of construction quality inspection in Table 1 that the quality pass rate of all engineering projects, whether sub-projects or sub-projects, is 100% for power transmission and transformation projects designed using this method. The construction quality of the power transmission and transformation project is high, and the safety performance is strong. The experiment evaluates the social and technical aspects of power transmission and transformation projects designed with 3D digital intelligent technology, and invites 20 well-known experts in power transmission and transformation engineering to evaluate the 220 kV transmission and transformation projects in a county designed using this method.

### Table 1. Technical evaluation results

| First level indicator                  | Secondary indicator        | Excellent | Good | Middle | Difference | Inferior |
|---------------------------------------|----------------------------|-----------|------|--------|------------|----------|
| Substation site selection             | Transportation conditions  | 0.8       | 0.1  | 0.1    | 0          | 0        |
|                                       | Engineering geological     | 0.8       | 0.1  | 0.1    | 0          | 0        |
|                                       | conditions                 |           |      |        |            |          |
|                                       | Device Selection           | 0.8       | 0.1  | 0.1    | 0          | 0        |
| Substation engineering design         | Planning and layout        | 0.9       | 0.1  | 0      | 0          | 0        |
|                                       | auxiliary system           | 0.9       | 0.1  | 0      | 0          | 0        |
|                                       | Route plan                 | 0.7       | 0.2  | 0.1    | 0          | 0        |
| Transmission line engineering design  | engineering design         | 0.9       | 0    | 0.1    | 0          | 0        |

From Table 1, it can be obtained that the proportion of persons with excellent evaluation grades in substation site selection is 0.8; the proportion of persons with good and medium evaluation grades are both 0.1; and the ratio of poor to inferior is 0. The ratios of good and good evaluation grades in the engineering design of substations are 0.9 and 0.1, respectively, and there is no medium, bad, and inferior; the ratios of good, good, and bad evaluation grades in the design of transmission line engineering are 0.8, 0.1, and 0.1, respectively. The evaluation results There is no difference or inferiority. It shows that from the technical level of the evaluation of the power transmission and transformation project, it can be seen that the power transmission and transformation project designed with the method in this paper has a good technical evaluation. Electrical engineering design is in progress.

### 6. Conclusion

A three-dimensional GIS power transmission and transformation engineering design review system, which features the following parts: used for three-dimensional design review management of power transmission and transformation projects, supports the application of three-dimensional design engineering, and effectively improves the quality and design level of the three-dimensional design of power transmission and transformation projects. The three-dimensional review system uses the EV-Globe platform for secondary development, including three-dimensional model loading and browsing, various design results data management centres, GIM model analysis and loading, review scoring and other management modules. The three-dimensional review system consists of three-dimensional review modules and Three-dimensional GIS module composition. The multi-layer scene engine is responsible for the import, management, rendering and interaction of multiple data of the scene. It is the core of the three-dimensional visualization system. The distance of the data area is far and near, and the data block of the appropriate resolution is selected for drawing, so as to achieve the closer the closer, the clearer the effect. According to the design idea of the level of detail model, the method of data organization and visualization of the global large-scale digital elevation model is realized, and the
method of visualization quality and performance is improved. Through the analysis of 3D visualization technology, review the project design drawings, combined with GIM technology to analyze the project as a whole, analyze the 3D visualization design drawings, and judge whether the design meets the requirements and specifications.

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