Three-dimensional visualization of secondary system based on digital twin

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Abstract. The digital twin technology has become mature and has entered the stage of popularization and application, but the research on digital twin technology of substation secondary system has not been carried out systematically. This paper provides the idea of digital twin digital analog integration application of secondary system, which realizes the information interconnection of three-dimensional model, loop relationship model and transmission data model. Through the correspondence between physical model such as optical cable and field reality, the physical loop information and corresponding virtual loop information can be viewed more intuitively. Combined with the multi-dimensional data-driven model technology, the correlation information of the secondary physical loop and the logic loop is dynamically displayed in 3D visualization, to provide technical support for the operation and maintenance.

1. Introduction

Digital twin technology has become mature and has entered the stage of popularization and application, but the research on digital twin technology of substation secondary system has not been carried out systematically [1-5]. At present, the State Grid is vigorously promoting the application of digital twin technology in the industry. There are also relevant research on 3D digital modeling, 3D design and 3D application both at home and abroad, and some research results have been achieved. However, the digital twin modeling and application of secondary system is still at the initial stage.

For the three-dimensional design of substation secondary system, equipment modeling is one of the main constraints to improve the efficiency. The direct and effective solution is ahead to make all equipment and material models related to the specialty into parametric three-dimensional models which require continuous modifications and maintenance, so as to form a professional three-dimensional parametric equipment and material device database with wide coverage and complete equipment types. Based on the full coverage parametric model library, the modeling workload can be reduced to the minimum, and combined with software programming to form an automatic design method.

Three-dimensional digital design makes each specialty carry out design work on the basis of unified coordinate system, model rules, layer division, measurement unit and drawing standard, which ensures the timeliness and integrity of engineering information. Digital 3D design is based on a complete and unified design coding system, so that the data carried by the created 3D model can be input once and used many times. It ensures the integrity, accuracy and uniqueness of the data source established in the process of engineering design. At the same time, it strongly supports the application of 3D data.
information in the whole life of the project, realizes the sharing of design data information, and effectively promotes the improvement of engineering construction, production operation and management level.

In the three-dimensional design platform, the 3D models of distribution equipment, cable trench, main transformer, the main control building of architecture, screen cabinet and Fire hydraulic pipeline of water heating specialty should be built. After that, the designer can directly measure and observe the relative position of the two devices in the plane. It greatly solves the problems of working drawing understanding deviation and asynchronous information exchange between different specialties.

After 3D design, the personnel channel is simulated in the model and check with the cable path. Then, the electrical and civil engineering professional designers conduct joint review of the model to intuitively adjust the layout and form of the bridge, so as to improve the design efficiency and quality, for example, as shown in Figure 1.

![Figure 1. Three-dimensional model of 750 kV project design.](image)

This paper provides the idea of digital twin digital analog integration application of secondary system, which realizes the information interconnection of three-dimensional model, loop relationship model and transmission data model. Through the correspondence of optical cable and other physical models with the actual situation on site, the physical loop information and the corresponding virtual loop information can be viewed more intuitively. Combined with multi-dimensional data-driven model technology, the secondary physical loop and logical loop associated information can be displayed dynamically in three-dimensional visualization to provide technical support for the operation and maintenance [6].

2. Three-dimensional visualization system of substation

2.1. Automatic design of physical circuit

Through the circuit function definition based on the general equipment code, the automatic design software is developed to realize the physical circuit design without the manufacturer's data. According to the corresponding relationship between the manufacturer's data and the general circuit code, the automatic matching is realized [7], as shown in Figure 2.
2.2. Automatic design of virtual circuit

2.2.1. Automatic mapping process of virtual circuit. Intelligent substation realizes digital network communication based on IEC61850 standard. By using advanced, reliable, integrated and environmental protection intelligent primary and secondary equipment, intelligent substation realizes the whole station information digitization, communication platform networked and information sharing standardization. At the present stage, the design of virtual secondary circuit mainly depends on the ICD configuration file of secondary equipment.

Through the virtual circuit function definition based on the general equipment code, the automatic design software is developed to realize the virtual circuit design without the manufacturer's data. According to the corresponding relationship between the manufacturer's data and the general circuit code, the automatic matching is realized [8-10].

2.2.2. Modeling principles. The general numbering principle is the numbering of sampling and GOOSE input: SVIN (1 ~ n); GOIN (1 ~ n); GOOSE output: GOOUT (1 ~ n) [11].

The input and output numbers of SV and GOOSE of each device are solidified to form a general device expression of virtual terminal.

2.2.3. Matching between virtual circuit and virtual terminal of actual substation. The whole platform design work is based on general equipment. The matching work of virtual circuit design and manufacturer terminal is a point-to-point process. The instantiated point-to-point work includes two parts: one is the point-to-point of device physical board port information; the other is the point-to-point of device virtual terminal [12-13], as shown in Figure 4.
2.3. **3D digital twin platform of secondary system**

2.3.1. **Architecture of 3D digital twin platform.** Three-dimensional design technology of substation engineering is an integrated innovation of modeling technology, information technology and network technology in the design field. Through the establishment of an integrated design platform, multi-disciplinary design collaboration and real-time information interaction can be realized, which can effectively improve the quality and efficiency of engineering design. Moreover, it is conducive to optimize the design, construction and installation, production and operation, and improve the intrinsic safety level of power grid engineering in the whole life cycle. It is an important means of building smart grid.

![Figure 5. Architecture of secondary digital twin system.](image-url)

Three-dimensional digital twin platform architecture application source layer technology: cross regional station control layer of multiple data source system data through, zipper, clear and splicing. Application data platform layer technology: multi-source data analysis, processing, collaboration and access. Application data access layer technology: data path, permission control and access authentication. Application service layer architecture technology: SpringCloud architecture mode is adopted to unify the gateway routing and call, so as to realize the system design mode of low coupling and high cohesion.

As shown in Figure 5, the overall system architecture is divided into four levels: pasted source layer, data analysis domain, data processing domain, access layer and application layer. The pasted source layer is responsible for data extraction, cleaning and conversion; the data analysis domain is responsible for daily data analysis and statistical processing; the data processing domain is responsible for transactional operation processing; the data access layer is responsible for encapsulation of access.
request interface, including verification of access rights and access logic. The application layer is the service layer, facing the user business logic.

![Diagram](image)

**Figure 6.** Data flow path of secondary digital twin system.

According to the application efficiency of data, the overall data flow of the platform is divided into two data streams, named offline data stream and online data stream, as shown in Figure 6. The offline data stream is extracted from external data source according to business rules and agreed frequency, and extracted, transformed and spliced from ODS layer to form standard data format, which is synchronized to data processing domain and analysis domain for business use. The online data stream is the protection business data entered from the platform, such as the addition and maintenance of account, the addition and maintenance of events and actions, the maintenance of patrol inspection records, etc. These parts of data need to be quickly synchronized through the message channel in the market or other data components for business real-time query.

2.3.2. Panoramic information coupling between virtual and real circuits of 3D digital twin platform. The designer of the equipment manufacturer configures the device physical port self-description (IPCD) file through the configuration tool to describe the device board and physical port in the IED equipment. The design company takes the IPCD file as an example to form the panel cabinet model, and then designs the optical cable connection between the panels and cabinets and the optical fiber connection between the devices to complete the design of the whole station physical loop configuration (SPCD) file. The design company can synchronously complete the SCD file design of the whole station through the device capability self-description (ICD) file, so as to realize the decoupling design of logical circuit and physical circuit.

The analysis process of panoramic information flow based on virtual real loop is to import SCD and SPCD files into the analysis tool to realize the virtual real integration design which can show the panoramic information flow corresponding to the virtual and real of the physical circuit and the logical circuit, clearly show the corresponding relationship between the physical circuit and the logical circuit, improve the design efficiency and accuracy of the intelligent substation, enrich the project site debugging methods, and improve the construction efficiency and convenience.

3. Application on visual perception technology based on digital twin in substation

In order to meet the requirement of building of EHV power grid, improve construction efficiency and quality. Based on a newly built 750 kV substation, this paper puts forward the application scheme of visual perception based on digital twin in 750 kV ultra-high voltage substation.

This paper studies the automatic imaging technology of total station for primary and secondary three-dimensional model: Based on primary three-dimensional model and secondary GIM model, according to the primary and secondary three-dimensional hierarchical structure of total station, the automatic
rendering, imaging and layout of primary and secondary three-dimensional model and hierarchical relationship of total station are realized.

Automatic imaging technology applied cable connection and loop connection: Based on the whole path of electric circuit and optical circuit and equipment relationship, the automatic layout and connection of equipment and circuit are realized.

Research data and model driven and perception technology: The driving and association of data to 3D model are studied to realize the dynamic change of 3D model.

Total station automatic imaging technology of primary and secondary 3D model: Based on a three-dimensional GIM model and a secondary three-dimensional model, according to the primary and secondary three-dimensional hierarchical structure of the whole station, the automatic drawing, imaging and layout of the primary and secondary three-dimensional model and hierarchical relationship of the whole station are realized.

Study the loop relationship model file analysis technology, analyze the model file and obtain the equipment code, coordinates, real loop connection relationship, equipment and facility hierarchical relationship. Study the secondary system object 3D model file analysis technology, and obtain the model, coding and other information of equipment and facilities. The visualization software completes the 3D imaging display of equipment and facilities by calling the corresponding coding model. Study the application of "fiber core automatic search algorithm" in three-dimensional model, which makes the secondary real circuit automatically route in three-dimensional space according to the three-dimensional coordinate relationship, and completes the three-dimensional imaging display of the connection relationship of optical cable, cable and equipment. The "virtual real correspondence" technology based on loop relation model and transmission data model is studied to obtain the virtual real loop information and realize the 3D fusion display of real loop and virtual loop. Study the data interface technology of digital twin model of secondary system, develop the external data interface, the terminal production data, video data, auxiliary control data, etc., realize the comprehensive perception and fusion of data and digital twin model of secondary system.

![Figure 7. Panoramic holographic dynamic display diagram.](image)

The digital twin visualization of secondary system imports and analyzes the digital twin model file of secondary system. Through the data interface technology, the information interaction between station end production data, video data, auxiliary control data and 3D model is realized. Using dynamic data-driven 3D model technology, 3D visualization of the whole scene of the substation is carried out, and a multi-view, immersive and interactive intelligent platform is built to realize the 3D panoramic holographic dynamic display of the whole secondary system 3D model and operation data. For the primary GIM model, the analysis and data interaction of the GIM model are carried out to realize the overall presentation of the primary and secondary 3D scene.

In this system, Panoramic holographic dynamic display is shown in Figure 7. For the broken chain signal data, by inputting the fault signal, the secondary circuit corresponding to the signal can be quickly located and visualized in three dimensions to realize the auxiliary troubleshooting, analysis and query of the fault. 3D visualization view of optical signal is shown as Figure 8. Visualization ratio of soft and hard platen and setting value is shown as Figure 9.
4. Conclusions & discussions
Combine with three-dimensional GIM platform, use digital twin technology, construct the application idea of digital twin digital analog integration of secondary system, and realize the information interconnection of three-dimensional model, loop relationship model and transmission data model. Through the correspondence between the physical model such as optical cable and the actual scene, the physical loop information and the corresponding virtual loop information can be viewed more intuitively. Combined with multi-dimensional data-driven model technology, three-dimensional visualization dynamic displays of secondary physical circuit, logical circuit associated information, to provide technical support for operation and maintenance. Based on the digital twin technology, the application of digital analog integration in the secondary system is proposed, corresponding to the design, construction, operation and maintenance of intelligent substation, which is of great significance in the application of power industry.

Acknowledgments
This work is supported by Shared Application on Transmission & Distribution Project and 5G Communication Technology project. This support is greatly appreciated.
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