Research on Application of Construction Model Based on 4D Visualization in Construction of Intelligent Substation

Chunguang Ren*, Yachen Wang, Kai Xue, Shenglong Zhi and Tao Chen

Economic and Electrical Research Institute, Shanxi Electrical Power Company of SGCC, Taiyuan 030002, China

*Corresponding author email: chunguangren@sgcc.com.cn

Abstract. At present, the existing technology has not yet realized the conversion process from the digital design model of the substation project to the construction model. This paper provides a solution to this problem. After the design model GIM is loaded into unity, the vertices and materials of the GIM model are read and loaded into the scene through the company's independent research and development of three-dimensional design software (STD-R). The model level information returned by the terminal corresponds to the loaded model one by one, thereby obtaining a model tree structure. The research results of the thesis provide convenience for the design and construction of power grid substation projects.

Keywords: 4D visualization, construction model, intelligent substation construction.

1. Introduction

With the continuous deepening of digital power grid construction and the continuous improvement of power grid engineering construction requirements, in the face of the characteristics of long construction period, many personnel, scattered equipment and materials, and trivial management operation processes, the traditional manual inspection and manual paper medium recording work methods are adopted. Has been unable to meet the requirements of engineering construction management and control. The use of informatization means to realize the innovation of the supervision model and to solve the problems of “weak supervision is not strong, backward supervision means” and other problems that have emerged in the construction of the project have become an inevitable choice for the management of power grid construction.

Relying on the three-dimensional digital achievements of the design unit, combined with the actual experience of the project and on-site needs, we use the "big cloud to move intelligence" and other digital methods to comprehensively build a new type of 5D construction management system for the visualized power grid project to meet the requirements of project digitalization, modernization, and leanness. Urgent requirements for management and information construction. In addition, the research results can provide different customers with tools and services in the process of power grid construction, and become a stable source of income for the company [1].
2. Overall system design

2.1. Framework description
Realize the whole process simulation of the construction site and strengthen the management system of the project construction process. The system consists of U3D client and JAVA server. The JAVA server provides data service interface and H5 page support. The U3D client serves as the rendering of the three-dimensional model and the final display of data. The information page in the client calls the H5 page of the JAVA server through WebView for final presentation. The overall framework is shown in Figure 1.

![Figure 1. Overall framework](image)

2.2. Working environment and process
All professional software is integrated in the Project Wise environment. The platform provides an integrated collaborative environment for the management of engineering project content. It is the main line of management for the entire process of project data and files from generation, editing and modification to operation and maintenance application. The platform focuses on information management, personnel management, process management, and standard management, and through good security access mechanisms, all project participants work together on a unified platform. Create a collaborative environment according to the needs of various professions, analyze the common points of the needs, distinguish the common and professional characteristics of the needs, in order to facilitate future management, consider the scope of application of the requirements, and place the requirements at a reasonable configuration level [2].

The data center establishes a corresponding directory structure on the PW platform according to the different stages of design. Each major has its own professional catalog, which is divided into different work localities in the professional catalog, and in each professional area according to its own work process is divided into Drawing drawings, Sheet drawings, proof sheets for finished products, receiving documents, three-dimensional models, funding documents, project contact sheets, grid layout, final assembly models, etc.

2.3. 3D design collaboration requirements and process
First, professional 3D modeling procedures should be carried out in strict accordance with the relevant regulations of the "3D Design Management Regulations". Second, check the progress of professional modeling. The project 3D coordinator and/or 3D technical coordinator should regularly hold a 3D
model progress review meeting according to the project 3D work plan to keep abreast of the design progress of each professional model, maintain the consistency of the design progress of each professional, and avoid the overall progress due to the lag of a few professional progress Procrastination occurs. The progress check should form the minutes of the meeting and be submitted to the 3D audit team and the production technology management department. Third, quality standards for professional 3D models. The 3D models completed by each major should be verified and reviewed (or approved by the project) to meet the modeling depth of the current design stage of the project (refer to the "Substation 3D Design Operation Rules". The model content is complete, the layout is basically reasonable, and there is basically no "error, "Leakage, collision", this major and other related major have completed preliminary coordination and cooperation, and there is basically no "non-technical" collision. Finally, the professional 3D model is confirmed. After the professional 3D model is completed in stages, it should meet the professional 3D model quality standards. The reviewer and the project 3D coordinator shall sign and confirm on the professional 3D model quality standard confirmation sheet. The confirmation sheet replaces the process card and serves as the basis for the professional 3D model production organization and quality control [3].

2.4. Model algorithm

After the design model GIM is loaded into unity, the company's self-developed three-dimensional design software (STD-R) reads the GIM model's vertices, materials and other information into the scene, and returns the model level information and the loaded model through the server. One-to-one correspondence, thus obtaining a model tree structure. Because the vertex information read by the design model is a Float type parameter, it needs to be converted into a three-dimensional vector or vertex coordinates for unity reading. Where face is the vertex information read out, and vec is the converted information.

Unity needs to control the position, scaling, and rotation of the model, so the matrix information needs to be converted. OSG matrix transformation uses the following formula: \( V' = MV \) where \( V \) is the node coordinate before transformation, \( M \) is the transformation matrix, \( V' \) It is the transformed node coordinates. All three are expressed in the world coordinate system. In the three-dimensional graphics program, we can use geometric transformation to achieve the following purposes. Represents the position of an object relative to another object, rotates and arranges the size of the object. Change the viewing dimension, direction and perspective method. The most commonly used transformations include: translation, rotation and scaling. You can combine these transformations to form a matrix and perform several transformations at the same time. The matrix is described in the form of row and column numbers. The following changes translate one point \((x, y, z)\) to another point \((x', y', z')\):

\[
\begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
T_x & T_y & T_z & 1
\end{bmatrix}
\begin{bmatrix}
x \\
y \\
z \\
1
\end{bmatrix}
= \begin{bmatrix}
x' \\
y' \\
z' \\
1
\end{bmatrix}
\tag{1}
\]

One of the biggest benefits of using matrices is that you can combine the effects of several matrix transformations by matrix multiplication. This means that when rotating and translating a model, it is no longer necessary to use two matrices. You can get a combined matrix by multiplying the rotation matrix and the translation matrix. This process is called matrix concatenation and can be expressed by the following formula:

\[
C = M_\text{2}M_\text{1}\ldots M_\text{2}M_\text{1}
\tag{2}
\]

In the knowledge, \(C\) refers to the new matrix generated after the combination, and \(M_1\) to \(M_n\) represent each matrix to be combined together. In general, we mean combining two or three matrices,
but in fact there is no limit. There is a Matrix 4x4.operator * auxiliary function in the Matrix 4x4 class to perform matrix cascading operations. When cascading matrices, we should pay attention to the order of cascading. The above formula reflects a matrix cascading rule from right to left. In other words, the actual effect of each matrix used to create a merged matrix appears in order from right to left.

3. Modelling of 3D design

3.1. Modelling of preliminary design stage of high-voltage substation project

The modeling of electrical primary equipment includes transformers/reactors, circuit breakers, disconnectors/grounding switches, GIS/HGIS, voltage transformers, current transformers, capacitors, surge arresters, post insulators, switch cabinets, wire fittings, etc. The three-dimensional model of electrical equipment should use a general model in the preliminary design stage. This model is based on the requirements of general equipment and contains geometric information and attribute information.

The relationship table between electrical equipment and attribute information in the preliminary design stage is shown in Table 1. The three-dimensional model should add equipment attributes to the model through the three-dimensional software to create a model library of electrical equipment. The important parameters of electrical equipment such as rated voltage, rated current, dynamic thermal stability, etc. can be added to the equipment properties; and the material code of the equipment can be added to various models according to the specifications of the material code of the State Grid Materials Department for later transfer when connected with the ERP system of the project unit.

Table 1. Relationship table between electrical equipment and attribute information in the initial design stage

| Serial number | Engineering Object Unit | Model depth DL |
|---------------|-------------------------|----------------|
| 1             | breaker                 | 300            |
| 2             | Isolating switch        | 300            |
| 3             | Current Transformer     | 300            |
| 4             | Voltage transformer     | 300            |
| 5             | lightning arrester      | 300            |
| 6             | Engineering Object Unit | 300            |
| 7             | breaker                 | 300            |

Taking GIS/HGIS as an example, the GIS/HGIS model in the preliminary design stage is shown in Figure 2. The same parts can be spliced at different intervals. The GIS/HGIS body can be a cylinder (bushing tube part) and a cuboid (equipment part). Represented in combination. Outgoing and incoming sleeves can be represented by cylinders or round truncated cones (the umbrella skirt on the sleeves can be generated by curve rotation. If there are many sleeves in the project, it will have a greater impact on the performance of the computer image. In more complex projects it does not mean casing umbrella skirt). Casing equalizing ring can be generated by curve frame and thickening along the axis after modeling. The primary terminal block is represented by a rectangular parallelepiped. The ground terminal board is represented by a rectangular parallelepiped, and the ladder operating platform can be represented by a simple combined model of cylinder and rectangular parallelepiped. Floor-standing exchange control regulations can be expressed in a rectangular parallelepiped. The key parts of this model include: GIS/HGIS bottom size (affecting the base size); the height of the body and the operating platform (affecting the charging distance verification of the casing); the size and installation height of the casing pressure ring (affecting the charging distance verification) ; The direction and angle of the primary terminal block (affects the angle of the lead wire).
3.2. Modelling at the design stage of construction drawing of high-voltage substation
In the construction drawing design stage of the high-voltage substation project, a power facility product model that meets the requirements of the depth of the construction drawing design content should be established. Among them, the main electrical equipment should be built according to the actual product shape of the winning bidder. The building structure and foundation should be built according to the actual shape. The company will combine material procurement, unify the model standards, and gradually transition to the three-dimensional product model provided by the winning bidder [4].

The modelling of electrical primary equipment in the design stage of construction drawings includes transformers, reactors, gas-insulated metal-enclosed switchgear, circuit breakers, disconnectors and grounding switches, current transformers, voltage transformers, parallel/filter capacitors, lightning arresters, post insulators, 3D models of switchgear, converter valves, transfer switches, resistors, cameras, wall bushings and other equipment and their main attribute information. Taking the main transformer as an example, the main transformer needs to reflect the main components of the oil pillow, body heat sink, high and low voltage sleeve, terminal box, and equalizing ring, as well as the position of the bushing terminal and the direction of the primary terminal board. And angle (affects the angle of the lead wire), the projected size of the oil tank part (including the oil pipe and the flushing type bushing) on the ground (affects the size of the oil sump), the size and positioning of the oil pillow (affects the shape of the wing part of the firewall and the size of the oil sump), The outer contour of the metal part of the main transformer body (influencing the verification of the charging distance of the bushing and the lead wire) [5].

4. Three-dimensional preview of the construction process risk warning
Based on the three-dimensional model, the three-dimensional model is initialized and loaded, and the effect displayed by the model is that the three-dimensional model associated with the process in the network plan is displayed and loaded according to the time according to the planned time in the network plan and the construction progress of the actual progress. , Obtain the task name of each process and the risk control measures contained in the process, traverse all the models under the process, the program uses the algorithm of the bounding box to obtain the centre point of the multiple models, calculate the display position of the process risk control measures, with three-dimensional The form presents risk control measures [6].

Through the construction preview method, realistically simulate the construction process, infer the construction process of each day according to the schedule of the network plan, present the risks and control measures that may occur in each process in a three-dimensional scene, and predict the problems encountered during the construction process. According to the risk measures in the rehearsal process, make a response in advance to avoid the occurrence of safety and quality problems during the
construction process, improve construction efficiency, and reduce the incidence of accidents. And the construction work can be adjusted reasonably through the comparative analysis of planned preview and actual preview [7].

The algorithm principle used to present the risk control measures in the three-dimensional scene: use the binary tree to traverse all models under this process to obtain the centre point of the model mesh attribute, add the centre points of all models and divide by the number of models to obtain the process bounding box (bounds), traverse the bounding boxes of all models under the bounding box, and recalculate the intersection point, which is the centre point of the process. Figure 3 shows all the models bound by the binary tree step-by-step traversal process. The preview effect is shown in Figure 4.

![Figure 3. All models bound by the binary tree step-by-step traversal process](image)

![Figure 4. Preview performance](image)

5. Conclusion
Three-dimensional design is a new generation of digital, virtualized and intelligent design platform. It takes three-dimensional space technology as a symbol and digital technology as a link to integrate design information from all majors. Compared with 2D design, 3D design is characterized by "space" and "digitalization". Applying 3D design to the actual engineering design of high-voltage substations, the spatial characteristics of 3D design can be used to achieve complex underground pipeline layout, optimized cable layout, collision inspection, construction simulation, visual display, etc.; use the digital features of 3D design, Can realize the main wiring design (such as extracting the main parameters required for the main wiring from the equipment properties, automatically generating the main wiring parameter table, etc.), electrical calculation (such as lightning protection calculation), engineering quantity statistics, material reporting, construction progress management, operation Dimension management, digital handover, etc. This article uses Bentley Microstation basic platform
as the three-dimensional modelling software to develop equipment modelling and basic model library construction; uses Bentley Substation electrical once professional application software to develop electrical three-dimensional design; uses BRCM and Autolay software for auxiliary cable laying design; Bentley Navigator is a three-dimensional viewing and review tool for the delivery of digital products. At the same time, a program interface was developed to integrate some existing electrical computing software into Bentley software to form a unified application software platform.

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