Three-Dimensional Design Method of Overhead Transmission Line Based on BIM Technology

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Abstract. Because of the high complexity and large scale of transmission line engineering, a large amount of data will be generated in the traditional two-dimensional (2D) design process, and the work of each stage is relatively independent. The design results are difficult to be effectively managed and integrated, and timely information interaction within and between specialties can not be achieved. BIM (Building Information Modelling) technology has powerful functions of digitalization and information management. This paper studies the application of BIM technology in three-dimensional (3D) design of overhead transmission lines. With the help of Revit platform and secondary development technology, combined with "Xinfu 110 kV transmission and transformation" project, a standardized family library of overhead transmission lines is established, and a set of algorithms for automatic sorting of insulator strings and automatic generation of overhead lines are developed, which realizes the parametric design of the lines in 3D environment. The whole process is centered on BIM information model database, which solves the problem of information management and interaction in traditional 2D design, and improves the design efficiency and quality.

1. Introduction

With the development of the economy, the construction of electric power engineering has been continuously strengthened. As an important part of electric power engineering, the scale of transmission line projects is also increasing. Due to the high complexity, long construction period and large geographical span of transmission line projects, a large number of data will be generated from the design to the construction. And they are always expressed in 2D drawings that have limited information expressivity and weak linkage, leading to low-level information sharing across different disciplines. BIM, which is widely used in the field of construction engineering, has achieved considerable results in digital design and information management. When it is applied to transmission line project, with a BIM software used for design, all information can be stored in a 3D BIM model. Then, information delivery, invocation and management can be implemented through this central model, which is convenient for all parties to view and make decisions. The work efficiency has also been greatly improved.

Based on the "Shanghai Jinshan Xinfu 110 kV transmission and transformation" project, this paper explores the application of BIM technology in the design of overhead transmission lines, and a 3D design method of overhead transmission lines based on BIM technology is proposed. Moreover, the comparison between the method in this paper and the traditional design method is made to provide a reference for the application of BIM in transmission line engineering.
2. Defects of the Traditional Overhead Transmission Line Design Method

In the traditional design method of transmission lines, after line selection and path optimization, designers need to conceive a 3D model of overhead lines based on a 2D base map, and then draw it into plane drawings. Meanwhile, the parameter information of each component is displayed or recorded in drawings or forms [1]. The design pattern described above uses 2D CAD drawings as information storage and transmission medium, there exists the following two defects.

First of all, in the 2D design environment, designers devote most of their energy to drawing, instead of focusing on thinking about optimization designs. In addition, when the design results are presented in 2D drawings, the spatial relationships between components and possible design conflicts cannot be visually and intuitively viewed. Lack of linkage between drawings also makes it difficult for engineering change.

Secondly, the design information stored in drawings or forms has limited expressivity, and it is extremely inconvenient to manage and inquire, so that the whole design process is isolated and passive. Besides, the point, line or surface elements representing components in 2D drawings do not have practical engineering significance and cannot automatically satisfy the spatial attachment relationship between components. For example, with the size of tower's cross arm changing, the type of insulator string on it may need to be changed, although it is still placed on the modified cross arm by the hardware. Moreover, the concrete parameter information of components is often specially arranged, submitted and distributed in numerous forms. In case of design changes, designers need to find and update the corresponding data manually, which is inefficient. If there is a demand you want to learn from the existing designs, you also inevitably read a lot of drawings.

Facing the problems existing in the traditional transmission line design, the application of BIM technology can solve them to a certain extent. Based on the BIM platform, the design results are no longer dependent on the plane drawings, but are delivered as 3D visual models for each participant to invoke and view. When the information in all phases of the project is stored in a central model [2], and all views are kept in a unified linkage, it will be easy to obtain, update and manage information, and the design results can be directly used interactively to help decision makers make accurate judgments.

3. The 3D Design Scheme of Overhead Line Using BIM Technology

Revit, one of the most popular BIM modelling software in the market for its creation and usage of "family" concept, is taken as the design platform in this paper. “Family” in Revit represents the set of components with similar appearance but different partial parameter values. Different types of components can be automatically created by changing the geometric and non-geometric parameters of the “family”. There are massed types of components in transmission line projects, with large workload of parametric modelling and difficult positioning between components. This paper thus makes the use of the secondary development technology, all kinds of models can be automatically created and fully named by driving parameters of “family”, thereby a standardized family library of overhead transmission lines is established. A set of algorithms for automatic sorting of insulator strings and automatic generation of overhead lines are also proposed, in order to realize the automatic invocation, generation, spatial location and correlation of components in Revit. Finally, the 3D parametric design of the transmission line is completed. The content above will be illustrated through the practical case.

3.1. Detail about the Project Case

The "Shanghai Jinshan Xinfu 110 kV transmission and transformation" project introduced in this paper is a typical overhead line project. The design of overhead transmission line mainly includes line selection and positioning, design of tower, insulator string assembly and so on. In this paper, the design of overhead transmission lines is divided into two parts - the design of towers and the design of other components. The towers whose function is to bear the load from conductors and insulator strings are classified into suspension supports and tensioning supports [3]. The other components hereinafter referred include conductors, lightning conductors, insulator strings, jumping strings, etc. Among them, the insulator strings composed of multiple insulators and hardware, are used for hanging conductors to
keep them insulated from towers and ground, and they can be classified into suspension strings and tensioning strings according to the type information of towers.

3.2. The Parametric Design Process based on BIM

After line selection and path optimization, the 3D BIM-based design of overhead line is shown in figure 1. Firstly, the 2D points in Revit are selected for towers according to the base map, with the elevation, path code and other information to be given. Then, the type selection and automatic modelling of towers are completed at points by invoking the standardized family library established in the early stage. Components will be created automatically at the specified position according to the information of the tower, including sorting the loop and phase sequence of the suspension strings or tensioning strings in the path of the overhead line, and generating the overhead line according to the sag formula. Finally, the model is adjusted in the 3D visualization environment to complete the design.

![Diagram of Standardized family library](image)

**Figure 1.** Design processes based on BIM technology.

In this paper, two key technologies are solved in the 3D design of overhead lines — the establishment and invocation of the standardized family library and the automatic generation and arrangement of other components based on the type information of towers. The detail of each process is described below.

3.2.1. Establishment of the Standardized Family Library. The equipment and facilities in the transmission line engineering are mostly standard. When store their geometric information and general properties in the form of standard parameterized family and named according to the delivery standard, the standardized family library of overhead transmission lines is established. The library developed with the secondary development technology in this paper includes towers and other components mentioned in section 3.1.

Components other than towers, such as insulator strings, are generally composed of hanging boards, suspension clamps and other components that are standardized ones from the design specification [4]. The family library of these assemble parts is built in advance to realize "invoke whatever is needed" when designing the insulator string by only modifying appropriate parameters. The difference between different types of insulator strings lies in the geometric and non-geometric features. After taking these features as the family parameters and uniformly name it according to the specifications and standards, a standardized family library of insulator strings is then established, in preparation for the subsequent parameterized modelling. Figure 2 shows the family of double tensile insulator strings built in Revit, named CTS (according to the naming specification of the digital delivery standard in electric power engineering).
Figure 2. Parametric model of double tensile insulator strings.

Considering the situation in actual projects where a lot of the same type but different versions of insulator strings will be frequently invoked, this paper makes the following efforts with secondary development technology to avoid repeatedly parameters modification. On the basis of library established before, the family information each component in the project belongs to can be read and then modified according to its version by invoke the functions provided in the Revit API (Application Programming Interface). Take the same one mentioned before as an example, the naming rule of each version follows the following format: CTS_ voltage class code_tower design number_project number (e.g. CTS_V50_A25_111600850Y).

Similarly, this paper establishes the standardize family library of towers and other components. In addition, if there are a large number of towers, the secondary development technology can also be used to read the position information for auxiliary positioning to improve the design efficiency [5].

The above automatic modelling function is realized by a .dll file programmed and compiled using C# language in Visual Studio. Moreover, an external application file is written for creating a button in the Revit toolbar, when users click it and enters information, the .dll file can be quickly invoked and interact with the program. In this project, "path point placement", "model selection", "insulator string generation", "overhead line generation" and other buttons are made in the toolbar. The required model then will be automatically created and uniformly named.

3.2.2. 2D Points Selection based on Base Map. Using the "import CAD" function in Revit, the base map with information of route selection stored in .dwg format can be imported. Figure 3 shows the plane view of the one whose information includes the 2D line and the version and location of tower.

Figure 3. Base map of route selection information in Revit.

When click the "path point placement" button in the toolbar, the box of "setting path point type" will appear (figure 4). By selecting "tower" and inputting information such as elevation, buried depth and path code, the program will read the interactive information and invoke the function of 2D path...
point generation to complete the 2D point selection. The points here belong to the parameterized annotation family whose parameters are type, elevation, path code and number. They represent the spatial position information of the point which is exactly the center of the tower bottom under the actual situation, providing necessary information for the following structural selection and automatic model generation.

**Figure 4.** “Setting path point type” check box in Revit.

### 3.2.3. Selection and Automatic Generation of Towers

In the traditional 2D design, after the route path is selected, designers often need to locate the towers by combining multiple horizontal positioning drawings. A lot of work is also spent on the coordination between drawings in the subsequent design, which is inefficient and prone to errors.

However, this paper not only realizes the 3D visualization of route, which is convenient for information viewing and decision-making, but also the tower model can be created automatically. Since the 2D points described in section 3.2.2 has already provide the positioning information of towers, designers only need to click the "model selection" button, select the corresponding point and enter the version information of tower, the program will invoke the function to automatically generate the tower model at that point. The function here is exactly the one that drives the family parameters including the elevation of the 2D path point, the version of the tower and other information given by users, then the corresponding models will be generated in Revit.

### 3.2.4. Automatic Matching and Sorting of Other Components

Different from the expression of 2D drawings, the information of towers and insulator strings on them in the 3D model no longer exists in an isolated and scattered form, but can be correlated with each other in an engineering sense to improve the utilization of information. Combined with the secondary development technology, this paper invokes the function of generating insulator string and overhead line in Revit to achieve automatic matching and sorting of components by reading the design information of towers.

Among them, the insulator string is attached to the tower at a certain angle, and its position relative to the tower can be regarded as fixed. An algorithm for automatic sorting of insulator strings is developed in this paper. Users only need to click the "insulator string generation" button, select the tower model, then choose the corresponding insulator string family, set voltage level and select the left/right position according to the prompt, the algorithm will number the loop and phase sequence for each insulator string in the path of overhead lines from top to bottom and from left to right. Finally, the insulator string model is generated automatically by invoking the function that can read the information of the tower, and adjust the angle according to the position information of the tower.

Based on the loop and phase sequence information of the above insulator strings, an algorithm for automatic generation of overhead lines is also developed. In order to make the model lightweight, the 3D model of overhead line can be represented as model lines in Revit. The stress-sag formula in overhead line design specification is taken as the constraint here. Since the two ends of the overhead line are connected to two adjacent insulator strings in the same loop and phase sequence, when the
function that can read the position information of the two insulator strings is invoked, with these information taken as the coordinate input, the overhead line models between the insulator strings in each loop and phase can be automatically created (figure 5).

Figure 5. Generated overhead lines in Revit.

3.2.5. Model Adjustment. In the 3D visualization environment, the adjustment of the model is easier and faster than the traditional CAD platform [6]. Obvious design errors can be detected in a timely manner and coordinated across the various views.

In addition, using the functions of automatic CAD plot and detailed list generation provided in Revit [7], plane-section drawing and acquisition of detailed list of towers and components can also be quickly realized based on a 3D central model.

3.3. Advantages of the Proposed Method based on BIM Technology

There are two major advantages in the proposed 3D method of overhead transmission line based on BIM technology.

Firstly, it can improve design efficiency and quality. The introduction of parameterized design method enables designers to get rid of the boring and complicated 2D plane drawing, they only need to invoke the standardized family library established in advance, that is, the 3D models of the towers, insulator strings and other components can be quickly generated. Besides, the spatial position relationship between components can be precisely expressed through the secondary development technology, designers only need to consider the selection of components, so as to focus more on the design and optimization. At the same time, based on the visualization BIM model, problems such as component positioning errors and location conflicts in the design process can be intuitively identified and timely adjusted [8], and all views are coordinated and unified, making it easy to change.

Secondly, the information utilization is obviously improved. Different from traditional 2D design, information including all ones regardless of component or the whole line are stored in the center of the same model, every participant can directly add, delete, modify and update them in time. The model also forms a complete database that is easy to manage and query the required data [9]. Moreover, the introduction of the family library can realize the reuse of components and greatly improve the utilization of knowledge.

4. Conclusion

Taking the project of "Shanghai Jinshan Xinfu 110 kV transmission and transformation" as an example, this paper successfully explores the application of BIM technology in the 3D design of overhead transmission lines. Combined with parametric design and secondary development technology, the automatic generation of the central model of overhead line is realized, which greatly improves the design efficiency and quality compared with the traditional design method. The research results also provide a reference for the future application of BIM technology in overhead line engineering.
Research on the BIM technology in China is in its infancy, and its application in power transmission engineering is still lacking experience [10], so further research is needed. This paper has not yet realized the BIM-based line selection and path optimization, that is, how to introduce BIM technology in the early stage to achieve the truly forward independent design and further take advantage of BIM collaboration and information sharing will be the direction of future research and exploration.

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