The Research on Approach of BIM-Based 3D Design for Transmission Line Project

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Abstract. BIM (Building Information Modelling) technology has the advantages of visualization and informatization. But BIM technology is mainly used in the construction field, and the application of BIM technology in transmission project is less. This paper research the application of BIM technology in the three-dimensional design of transmission lines. Based on the Revit platform and using secondary development technology, the parameterized model library of transmission line was built by Revit, such as work wells, cable trenches and towers, and the three-dimensional curve fitting algorithm was applied to design the path of the transmission line, and finally the three-dimensional digital model of the transmission line was built. The research results in this paper can provide a new method for 3D design in the field of transmission project.

1. Introduction
The emergence of BIM (Building information modelling) technology has brought a second revolution to the construction industry and promoted building informatization [1]. BIM technology subverts the traditional design process and improves design efficiency. The traditional process of architectural scheme design is that the architect completes the architectural design and architectural drawings, and then delivers them to the structural engineer to complete the structural design, and finally completes the structural construction drawings. Once the scheme is changed, a large number of drawings need to be repeatedly coordinated among different professions and modified. When adopting BIM technology for design, multi-specialty collaborative design, such as architecture and structure, is convenient for information exchange and scheme adjustment. In addition, BIM model can store all the design information in the whole life cycle of the building, which is of great significance for guiding the design, construction and management of the building.

BIM technology has some successful cases in the field of construction and is rapidly developing, but currently BIM technology is rarely used in power transmission projects and is still in its infancy [2]. At present, transmission engineering is still dominated by two-dimensional design, and CAD drawings are mainly used to deliver design solutions [3]. Compared with general construction engineering, power transmission engineering has the characteristics of large space span, large amount of engineering, and complex and changeable design. Using two-dimensional design means, a large number of floor plans will be generated during the design phase, which consumes a lot of time. Therefore, it is suitable to use BIM technology. Based on the “Xinfu 110 kV transmission and transformation” project, this paper explores the application of BIM technology in the three-
dimensional path design of transmission engineering, and provides a reference for the application of BIM technology in transmission engineering.

2. Defects of Traditional Transmission Line Design Methods

At present, the transmission line design method is two-dimensional design, and the plan CAD drawing is used as the final design result. This design method has obvious disadvantages.

First, two-dimensional graphics are more abstract than three-dimensional graphics, making it difficult to express and convey information. During the initial design phase of the scheme, designers used two-dimensional drawings to communicate and negotiate different design development schemes. Since the two-dimensional graphic expression is not intuitive enough, designers need to communicate and check repeatedly, which is inefficient and prone to errors. When the design plan is changed, due to the connection between different two-dimensional drawings, it may be necessary to modify it. For power transmission projects, the number of drawings is large, which may cause errors or omissions.

Secondly, the information content of two-dimensional drawings is small. On the one hand, the main information expressed in the drawing is graphic information, including geometric information and geographic information, etc. For other information, such as component parameters and performance parameters, it needs to be marked separately in the drawing text, and it is difficult to fully express. For designers, it is necessary to check repeatedly when designing drawings, which is time-consuming and labor-intensive. For construction workers, it takes more time to read the drawings and the information transmission efficiency is not high.

Also, for transmission projects, the design of line paths is a very important part, and it is very inconvenient to use two-dimensional drawings to transfer path design information. The path of the transmission line is three-dimensional, and the cable direction may change with the terrain. The two-dimensional design drawing is a plane projection of the three-dimensional model [4]. In addition to the plane alignment, information such as elevation must be marked at an appropriate position to express it [5]. This is not efficient in design drawing and construction reading.

To sum up, it can be seen that for transmission projects, the current two-dimensional design method is too large, with low level of data integration and informatization. So it is necessary to adopt BIM technology for transmission line design.

3. Design Method of Transmission Line based on BIM Technology

In this paper, Revit 2018 software is used as the design platform to realize the three-dimensional path design of transmission lines through secondary development technology. Autodesk Revit is built for BIM and has powerful design modeling capabilities. The Revit model is composed of parametric families. Parametric-based design can realize batch component generation and editing, which greatly improves modeling efficiency [6]. Revit software also provides additional modules for users to expand. Revit's secondary development is realized through the API (Application Programming Interface) provided by Revit software, which can realize the three-dimensional design method of transmission path based on BIM technology. Although Revit provides complete modeling capabilities, Revit software has poor modeling efficiency for non-conventional components in power transmission systems, such as industrial wells and pipelines. Therefore, the Revit function is extended through secondary development to achieve Three-dimensional path design. In this paper, Microsoft Visual studio software and C# development language are used for Revit secondary development. By calling Revit API function, dynamic link library file is compiled. Then, Revit plug-in with transmission line design function can be realized.

3.1. Case Study

The transmission line project introduced in this article is the Xinfu 110KV transmission line, which includes both underground cable lines and overhead lines. Among them, the underground cable line contains the component mainly by the work well, the cable ditch, the discharge pipe, the cable.
Overhead lines include poles and towers and other accessories, such as insulator strings, conductors, wire fittings, etc.

This article explores the three-dimensional design of transmission lines based on BIM technology. The design idea is as follows: Firstly, preliminary design was conducted according to the topographic map to determine the position of each component. Then, two-dimensional path points were arranged in the plane plan and relevant parameters were set according to the preliminary design scheme. After the layout is completed, the 2D path point parameters are read, the predefined parameterization family is called, and the point-based 3D model is generated, including well, cable trench, pole tower and so on. After the 3D model is generated, channel paths can be generated to complete the line connection logic. Channel paths can be divided into curves and polylines according to their line types. Then, the structure such as a pipe is generated on the basis of the channel path. Finally, based on the three-dimensional model and the formation of the tube, the cable design is completed, and the entire transmission line design is completed. Figure 1 is a flowchart of circuit design based on BIM technology.

Figure 1. Design processes based on BIM technology.

3.2. Create Point-based Parametric Component Families

After the preliminary design is completed, the route and path planning is basically determined, and preliminary modeling can be completed in Revit.

The first step of modeling is to complete the arrangement of two-dimensional path points. The two-dimensional path points are actually predefined parameterized families, which are composed of two system families: filled area and label. The two-dimensional path point family contains the parameters: symbol type, path code, number, selection notes, buried depth, elevation, etc. The symbol type refers to the type of engineering structure represented by the point, including work wells, cable trenches, buried points, and towers. The path code refers to the code of the transmission line to which the path point belongs. In a three-dimensional model of a transmission path, multiple transmission paths may be included. The cables between different paths are independent. In order to facilitate the design and verification of cables during the cable design, the family attribute of path code is introduced. The number represents the order of the engineering structure on a certain transmission path, arranged from small to large. The selection annotation represents whether the two-dimensional waypoint has completed the symbol selection, and the unselected path point cannot generate the corresponding engineering structure in the subsequent modeling steps. The burial depth and elevation information represent the three-dimensional geographic information corresponding to the engineering structure represented by the path point. Through these information, the three-dimensional coordinates of the three-dimensional model of the engineering structure can be determined directly to complete the three-dimensional modeling.

When the 2D waypoint arrangement is completed, the auxiliary path function can be used to verify whether the 2D waypoint arrangement is correct. Auxiliary paths are formed by sequentially...
connecting the path points from small to large on the same path, so designers can check the connection order and logic of the lines to avoid deviations between the actual modeling and the design scheme. Figure 2 is a schematic diagram of a two-dimensional path point and an auxiliary path.

After ensuring that the 2D waypoints are arranged correctly, a 3D model can be generated based on the 2D waypoints. These 3D models are pre-designed loadable parameterized families, which can realize rapid generation of 3d models without manual modeling by designers.

The following is a brief introduction of how to generate 3D models for different categories of 2D path points. For standard wells (figure 3), when the "model selection" function is used, the software will automatically read the parameter information of the corresponding 2D path after the 2D path point is selected, such as symbol type, elevation, burial depth, etc. When the software reads that the symbol type of the path point is a standard industrial well, the family library of standard industrial wells is automatically called. The family library includes standard linear industrial wells, standard three-way industrial wells, standard four-way industrial wells, and standard corner industrial wells. After selecting the type of industrial well, the geometric size of the industrial well can be set if the designed shaft size is the same as the preset default value, there is no need to modify. After completing the parameter settings, a 3D model can be automatically generated. If the model angle does not match the design, it can be manually adjusted. For cable trenches, the structure is actually similar to industrial wells, they are both concrete structures and arranged by cable racks. Cable trenches are usually adjacent to the poles to achieve the conversion of underground cables and overhead cables. The method of generating cable trenches depends on special-shaped industrial well drawing tools. For pole towers, the generation process calls a predefined parameterized family to achieve rapid modeling.

After the arrangement of the two-dimensional path points is completed, a three-dimensional channel path needs to be generated. Channel paths are used to connect two-dimensional path points using smooth curves. For the path between the work wells or between the work well and the cable trench, it is usually a smooth curve, which can be used to stake out and generate power drainage pipes and non-excavated pipes. At the same time, the drainage pipes and non-excavated pipes indicate the line type of the transmission cable and towards. For poles and poles, the path of the passage is a polyline or a straight line. This is because the cable types and arrangements on the poles and towers are more
complicated. Generally, another algorithm or custom drawing is used to design the path. The channel path generated here only represents the connection logic.

The steps for generating a 3D channel path based on a 2D path point are as follows: First, the designer selects the 2D path point through which the 3D channel path passes. Before generating a path, it is necessary to first determine whether the designer has selected a path point for errors. There are two cases for the wrong waypoint selection: the first case is that the selected waypoints are not all on one path, that is, the path codes are different; the second case is that there are unselected waypoints in the selected path, for the same reason as mentioned above, for different types of two-dimensional path points, the path generation method is different. After the two-dimensional path point selection is completed, a three-dimensional path control point needs to be generated, and the three-dimensional path control point is used as the start or end point of the three-dimensional path. Depending on the symbol type of the two-dimensional path points, the method of generating three-dimensional path control points is also different. For industrial wells, due to its own volume, the channel path does not run through the industrial well, but the connection points at both ends of the industrial well are used as the start and end points of the channel path; for the direct buried point, the start and end points of the channel path coincide with the direct buried point. After the 3D path control points are generated, a 3D channel path is formed between the 3D path control points corresponding to the 2D path points adjacent to each other on the same path, and a 3D channel path is generated between every two 2D path points.

The following describes the algorithm for generating 3D channel paths (figure 4). The curve used for the channel path is NURBS curve (Non-Uniform Rational B-Splines, non-uniform rational splines). NURBS curve has the characteristics of geometric continuity, tangent continuity and curvature continuity [7]. Chong Jian NURBS function curve is called NurbSpline class CreateCurve method, which may be generated by passing the control points and weight parameters NURBS curve. Each channel path is composed of three NURBS curves connected end to end. The first and last two segments are composed of three control points, the middle segment is composed of seven control points, and all control point weights are set to 1. The tangent direction of the starting point of the first section of the curve is perpendicular to the side of the working well at the starting point. Similarly, the tangent direction of the end of the third section of the curve is perpendicular to the side of the working well at the end. At the same time, both curves are NURBS curves in the horizontal plane, thereby ensuring smooth curve transition.

![Figure 4. Three-dimensional channel path.](image)

3.4. Create Line-based Parametric Component Families

After the path of the channel is generated, a power pipe can be generated between the work well and the cable trench. Power pipe is the most commonly used cable laying scheme for underground transmission lines. Its advantages are high strength and small frictional resistance on the inner wall, which can reduce the layout of the work well. When using the "Generate Pipe" function, first select the 3D channel path and the industrial well to be connected, and then parameters need to be set. The parameter settings include the diameter of the pipe, the arrangement of the channels, and whether to create a new one. There are usually 150 mm and 175 mm bore diameters. If necessary, they can be
mixed and used. There are many ways to arrange the channels, usually no more than three rows, each row does not exceed 10. When two apertures are used in combination, the upper row or two rows are 150 mm aperture, with a row of 175 mm apertures below. Whether the newly created parameter represents whether the pipe is an existing component. For a non-new pipe, the occupied aperture can be defined, indicating that the cable has been laid in the aperture.

For different lines, due to the different path paths, it is difficult to complete the pipe generation by the predefined loadable family. Therefore, the method used in this article is to generate the built-in family based on the designer's input. Enter the parameters to generate a rectangular section, stretch the loft to generate a band structure, and then draw the section according to the aperture design parameters. Figure 5 is a schematic cross-sectional view of a power drain pipe.

![Figure 5](image)

**Figure 5.** The cross section of electricity channel.

### 3.5. 3D Cable Design

After the point-based 3D model and channel path have been completed, the cable design can be carried out, and the last part of the transmission line design is completed. Similar to the channel path, for the type of three-dimensional components, the arrangement of the cables between them is also different.

The following describes the connection methods of cables between different types of 3D components. For industrial wells and cable trenches, the connection channel between them is the pipe, and the pipe channel is the cable duct. After the tube is generated, the cable design can be completed using the "Cable in tube" function. Since the tube is generated by staking out the channel path, the curve form of the different channels is the same as the channel path, and the cable is generated using a similar method. For the well itself, because of the convenience of maintenance and protection, the cables are usually distributed on the rack. Generally, the arrangement of the cables on the rack is arbitrary, and the designer can freely set the position of the cables on the rack. After the cables in the adjacent pipes at the two ends of the shaft are generated, the cable can be quickly generated by selecting the first cable and then selecting the supporting legs in turn, and the curve is also the NURBS curve. Figure 6 is a schematic diagram of cables in a shaft. For the connecting cable between the cable trench and the pole, the structure of the pole is more complicated, and the cable direction generally does not follow a fixed path. Therefore, the "custom draw" function is used to draw the cable. The custom cable uses the cable end point or connection control point as the start and end point, and can connect two cable end points or any control point. The end of the cable trench cable can be used as the starting point, and the suspension clamp or tension clamp of the pole insulator string can be used as the end, and the middle point of the cable can be selected to quickly generate a smooth cable. The custom drawing function enables the designer to complete the cable design for almost all scenarios, with strong generalization. For the overhead cable, the generation of it can be realized by selecting the wire clip corresponding to the adjacent tower.

Finally, when the cable design is complete, cable connector settings can be made. Cable joints are usually arranged in the work well and cable trench. The specific implementation principle is that after the position of the cable connector is selected, firstly by introducing a pre-defined loadable family, by reading the information of the selected cable, the layout position and rotation angle of the cable interface are calculated, and then the original cable is broken and carried out. Rebuild to complete the layout of the cable connectors. Figure 7 is a schematic diagram of a cable connector.
4. Advantages of BIM-based Design Methods

Compared with traditional design methods, the transmission line design method based on BIM technology realized in this paper has powerful advantages in terms of design efficiency and information management.

The design method based on BIM technology can greatly improve the design efficiency of designers. The reason is that the method is in line with the idea of parametric design. By pre-defining a parametric component library including components such as wells, it can achieve fast 3D modeling and effectively reduce modeling time [8]. At the same time, compared with two-dimensional drawings, the three-dimensional model has the characteristics of three-dimensional visualization, which is more conducive for designers to collaborate during the optimization and adjustment phase of the scheme. When the model is modified, the model can be modified only by modifying the component properties in most cases, which is more efficient than traditional CAD design.

On the other hand, the design method based on BIM technology is more complete in terms of information management. BIM information can not only store model geometric information, but more importantly, it can store attribute information other than geometric information, that is, the model file is used as a medium to form a central database, which contains the information of each stage of the entire project. For the traditional design method, the information in different stages of the project is decentralized and stored, the degree of information integration is low, and the management is difficult [9]. Therefore, the design method based on BIM technology forms a unified and integrated data management solution, which improves the data sharing rate and delivery efficiency, improves project collaboration efficiency, and reduces project management costs.

5. Conclusions

This article takes "Xinfu 110KV transmission line" as an example to explore the application of BIM technology in the three-dimensional design of transmission lines. This article uses Revit The secondary development method, through the establishment of a parametric model, realizes the rapid establishment of 3D models such as industrial wells, and automatically generates the path of the channel to complete the cable Design to achieve three-dimensional design of transmission lines. Most steps of the entire process are automatically completed by software, which has changed the design method of traditional transmission lines, and also improved the informatization of transmission line projects.

The research results of this paper prove that BIM technology can play a huge role in the field of power transmission and transformation. Meanwhile, the research results of this paper can provide reference for the application of BIM technology in power transmission and transformation engineering in the future. Of course, the research results of this paper also have many shortcomings, such as the channel path generation method is relatively simple, and may not be exactly the same as the actual, which need to be adjusted by the designer alone.

Although from the current point of view, the application of BIM technology in the field of power transmission and transformation is very limited, but BIM technology is currently undergoing rapid development. The widespread application of BIM technology in power transmission and transformation projects is just around the corner [10].
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