Research on Auxiliary Construction System of Transmission Engineering Based on 3D Digital Achievements

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Abstract: In order to take full advantage of the three-dimensional digital design data and solve the traditional construction schemes' problems better, characteristics of three-dimensional digital data and the shortcomings of traditional construction management methods in the paper are analyzed. The organization management mode of 3D digital results is studied to construct a full information 3D model library by combing the relationship between models, attributes, documents, drawings, etc. On the basis of this, combined with the construction process of transmission engineering, a three-dimensional auxiliary construction application platform for transmission engineering based on three-dimensional digital design results is established. Through the software platform to manage, process, analyze and mine massive data, on the one hand, the integration, interaction and sharing of multi-source heterogeneous data are realized; on the other hand, the three-dimensional digital technology is applied to the construction process to realize the three-dimensional visualization of the construction process of the transmission engineering, thus providing a new solution for solving the construction problem.

1. Introduction
With the continuous expansion of the scale of power grid construction projects, engineering construction is becoming more and more complicated. The traditional construction management model with engineering drawings as the core is not enough to meet the needs of modern construction management, which is urgent to find some new technical means or methods to achieve new progress. At present, with the in-depth development of 3D digital technology [1] [2] in the application research of engineering projects, auxiliary construction cases based on this are constantly emerging.

Currently, the State Grid Corporation of China has clearly proposed that the transmission engineering carries out three-dimensional digital design, which is of great significance for accumulating the digital basic data of transmission engineering. However, due to the complexity of these data, its use value is relatively low. Therefore, relying on the three-dimensional design results, the mobile Internet, Internet of Things and three-dimensional digital technology will be applied to the construction site of the transmission engineering, which can give full play to the value of the three-dimensional digital design results, and further improving the safety and quality management of power grid[3] construction projects will be one of the important propositions for the next phase of research.

Therefore, it is of great significance to carry out research on the application of auxiliary engineering for the three-dimensional design of power transmission engineering, to realize the
information, information, standardization and visualization of engineering construction, to improve the quality of transmission engineering construction, the level of construction management[4][5] and to accelerate the digital information construction of transmission lines.

2. 3D design results and characteristics

2.1 Data composition
The digital engineering data of the transmission line mainly includes the 3D design engineering geographic information data, 3D design model and related documentation involved in the preliminary design stage, construction drawing design stage and completion drawing design stage, which the specific content is shown in Figure 1.

![Figure 1. The three-dimensional design achievements data of transmission engineering](image)

2.2 Data characteristics
As mentioned in the previous section, the data characteristics of the 3D digitization achievements of the transmission engineering basically have the 3V characteristics of the grid big data.

1) Volume. With the continuous deepening of digital design and the increasing degree of refinement, the amount of data of individual data models such as geospatial data and 3D design models is increasing, which result in an increasing amount of data. It jumps to the PB level (1000 T), E (1 million T) or Z (1 billion T) from the TB level of the traditional power grid.

2) Variety. There are many data sources for 3D design results of transmission lines, involving different design stages and different data formats; there are digital 3D models, engineering geographic data, and many electronic scanning files, documents, etc.; there are structured data, half structured data, and many unstructured data. In short, its modality is diverse and typical of multi-source heterogeneous data, which poses challenges to the organization, management and analysis of data.

3) Value. The 3D model and various data, documents, drawings, etc. realize digital interaction with each other through association, and integrate into the GIS platform. Through information data association and linkage control, construction risks and safety hazards can be better predicted, and construction feasibility can be verified.

Therefore, if these data can be applied to the construction assistance of the transmission project, it will surely bring greater value to the digital achievements.

3. Demand analysis
Through comprehensive investigation, the construction of 3D digital results assisted transmission engineering can be mainly studied from mechanized construction, temporary construction simulation, paperless construction, environmental protection and water conservation.

1) Mechanized construction simulation.
Due to the scattered construction site on the project site, the narrow construction surface and the complicated and variable construction site, the application of mechanized construction[6] in transmission line engineering is seriously restricted. It is necessary to provide the functions of mechanical equipment approach trajectory simulation, operation process trajectory simulation, and safety distance check with peripheral equipment and facilities during the construction process of
transmission line [9] [10] through mechanized construction simulation research.

(2) Paperless construction
The traditional construction process conveys the construction drawings in the form of two-dimensional paper drawings. The paper drawings are not only easy to wrinkle, easy to corrode, but also difficult to inquire, which is difficult to save. Therefore, the paperless office can be realized on the construction site by replacing the drawings and documents with the mobile terminal.

(3) Three-dimensional auxiliary design for construction
Due to the complex and ever-changing environment of the construction site, many temporary constructions are built by construction workers without planning. Many construction units are more casual when deploying the tension field. There is no reasonable planning land area, which leads to higher compensation costs, and sometimes even certain security risks. Therefore, it is necessary to quickly complete the temporary construction design plan according to the site environment and make overall planning in advance.

(4) Transmission line construction approach and environmental protection and water conservation
At present, the construction mode of transmission line construction [11] [12] [14] [16] machinery mainly relies on manpower for planning, and the use of public road data is less, and the selected paths are mostly paths that have been investigated or are more familiar. Some construction machinery is not the optimal path in the transshipment process, which result in waste of transshipment costs. In addition, the residual soil treatment plan at this stage is often after the completion of the construction, according to the on-site residual soil for on-site planning, the local soil that can be treated on site is treated locally, and the remaining soil that cannot be treated on site is not well planned. The processing method is more random.

4. System design
Based on the characteristics of 3D design results and the actual needs of transmission engineering [7] [8] construction applications, detailed analysis in the paper has been carried out from the aspects of system design, database architecture design and function module design.

4.1 Overall design
The system adopts the overall design scheme combining B/S mode and C/S mode, which is logically divided into multi-layer architectures of business layer, application layer, access layer and data layer. The architecture of the system is shown in Figure 2.

![Figure 2. System architecture](image)

Business layer. It realizes various business requirements based on 3D models in power transmission engineering based on various basic functional modules provided by the system, which is a professional functional layer of the system.

Application layer. The collection layer of the basic function modules of the system is used to access, process and analyze the underlying data, and provides tools for the business implementation of the upper layer.

Access layer. It link the application layer and the data layer to access the attribute data in the relational database through ADO or ODBC, access the spatial data through the spatial data engine, and access the file through file retrieval.
Data layer. All data storage of the system is located to support the normal operation of the entire system. The database is unified planning, deployment and authority management according to the data characteristics of the grid data. The bottom layer uses the MySQL database. The file system manages file class data, the spatial database manages graphic data, and the two-dimensional table are directly stored in MySQL.

4.2 Database Design
In the system logic structure design, the data access layer is the core module between the link application service layer and the data management layer. As the basis of the application service layer, the data access layer is responsible for providing space, attributes, and document data access to the application service layer. At the same time, as the extension of the data management layer, the data access layer shields the data source from multiple sources, heterogeneous, and distributed differences, and provides a unified data access service. The focus of the system data interaction design is to coordinate the data application requirements of the application service layer and the data service requirements of the data management layer. Various data access services are provided in a convenient and fast manner according to the data management and storage management mode of the data management layer.

According to the composition and characteristics of engineering information, the whole database is divided into five parts, which is comprehensive information database, model database, engineering database, system management library and vector database.

The vector database adopts the construction method of the spatial database, and the data interaction between the application layer and the database is completed through the spatial data engine. The data exchange between the remaining four sub-libraries and the business layer is completed by the persistence layer. The persistence layer is equivalent to the cache of the database table in memory. When the business layer retrieves or updates the data, the corresponding data table or data set is passed to the persistence layer that calls the corresponding method to complete the operation and returns the result. The overall data architecture is shown in Figure 3.

4.3 Basic function design
According to the application requirements and database architecture design of 3D design results of power transmission engineering, this paper combs the main functional modules of the system from the perspective of construction application, which its application area cover mechanized construction simulation, paperless construction, construction of 3D auxiliary design, and environmental protection and water conservation. The functional design of the specific module is shown in Figure 4.
System initialization. The server configuration connects to the database server, loads basic data such as basic geographic data, and builds a basic environment for the establishment of engineering solutions.

Engineering data import. Design the corresponding data interface to complete the overall import of engineering data, including the connection relationship of various models, files, attributes and drawings.

Scene construction. Supporting data interaction between data application layer and each data sub-library realize convenient call of 3D design results, and build 3D scenes on demand.

Browse display. The basic functions such as zooming and roaming of 3D scenes are realized; the detailed browsing of model data, the view properties, and hook drawings and file extraction are realized.

Three-dimensional analysis. The spatial three-dimensional analysis functions are realized of including approach path analysis, environmental protection and water conservation, and ground-line display analysis. It also has three-dimensional measurement and three-dimensional annotation functions to provide technical support for paperless construction.

Achievement export. Plan layouts, data sheets, etc. can be exported.

4.4 Professional function design
On account of the above basic function modules; a professional function module in the paper is designed for the construction process according to the construction process of the transmission line.

4.4.1 Mechanized construction simulation
(1) Construction process simulation. In the three-dimensional virtual scene[15], the simulation of the construction process is carried out according to the actual situation of the construction site. We simulate the order of entry and exit of equipment during the construction process, the trajectory of the
vehicle when the equipment enters and exits, and the scope of operation of the equipment during loading and unloading; also ensure that on-site problems caused by different reasons are reduced during actual construction.

2) On-site construction atmosphere. All construction equipment is modeled according to the construction site. Before the construction starts, the model is used to simulate the real scene in the three-dimensional virtual scene, such as the walking path of the vehicle when the equipment enters the field; and during the construction process, the placement of the construction tools and the position of the personnel. Simulate the situation of equipment that may be encountered and the construction of the vehicle to achieve a controllable state during the construction process.

3) Ground wire display simulation. During the construction of the grounding line, the construction personnel input the meteorological data measured at the construction site, including parameters such as temperature and wind speed; then the three-dimensional construction application system of the transmission line will automatically read the parameters of the wires, ground wire and cable in the gear, calculate in real time, and directly give the value of the sag under the current meteorological conditions, which is convenient for the construction unit to make the measurement comparison.

4) Safety distance check. According to the simulation of the construction process, the safety distance of the construction work area is measured for different working processes.

4.4.2 Paperless construction
(1) Model data is viewed separately. For construction projects, we can select a device or facility to view individual information as needed.

(2) Viewing model parameter information. According to the selected equipment and facilities model, the corresponding attribute information can be directly viewed, which include design attributes, equipment attributes, civil construction attributes, personnel information during construction, and machine information.

(3) Viewing Document. We can correlate the documents such as drawings in the design stage with the model. In the 3D simulation scenario, we can also select the model to filter the corresponding document information and view it directly.

4.4.3 Three-dimensional auxiliary design for construction
(1) Construction of a three-dimensional model library. According to the requirements of the construction of the construction site project department, all the facilities required for the construction of the project department will be three-dimensionally modeled for the construction of the temporary construction facilities of the project department.

(2) Design of the temporary construction plan. The construction personnel shall, based on the model data of the project site and surrounding facilities, and the model data of the temporary construction model library, formulate design plans for temporary buildings and facilities.

(3) The construction of the temporary facilities will be set up. According to the situation of the construction site at the construction site, the construction of the temporary construction facilities will be carried out. According to the different terrains, the corresponding templates are used in the system to simulate the layout and construction of the temporary facilities.

(4) Exporting Achievements. According to the layout of the temporary construction site and the fence of the temporary construction site, all the layouts of the temporary construction will be exported to a layout plan.

4.4.4 Construction approach, environmental protection and water conservation
(1) Construction approach planning. The coordinate information of each tower, the model of the tower and the foundation, and the required construction machinery model data are read from the 3D design results. The system reads the public road network data, selects the road according to the limit width, height limit, and weight limit in the road network data, and performs path planning work according to the location of the set construction project department.
(2) Remaining soil treatment scheme. The system calculates the amount of residual soil generated by the foundation construction, and then uses the topographic data to calculate the amount of residual soil that can be absorbed locally, and then rationally plan the external transportation plan.

5. Implementation and application

5.1 System development environment and method
The development of the entire system[13] is based on .NetFramework4.0 and is implemented as an integrated development environment using MicroSoft Visual Studio 2015. The spatial database uses MySQL as the underlying database, and then uses ADO.Net to access the attribute data and access the spatial data through SDE. EVGlobe is used to realize 2D data acquisition, editing, maintenance and 3D design and results display. The MVP framework is utilized to control human-computer interaction logic and implement human-computer interaction interface based on DevExpress.

5.2 Mechanized construction simulation
Mechanized construction simulation applications mainly include three steps, which are mechanized construction plan preparation, mechanized parameterization configuration and mechanized construction simulation application.

Mechanized construction plan preparation: According to the mechanized construction requirements of the construction site, the construction personnel prepare the mechanized construction plan as the basis for the mechanized construction simulation.

Parameterized configuration of mechanized construction: According to the mechanized construction plan, the construction personnel configure the parameters of the mechanized construction simulation that include construction operation information, machine tools, work trajectories, operation procedures and steps, such as the action path of the vehicle when the equipment enters the site; as well as the placement of the construction equipment and the position of the personnel during the construction process.

Mechanized construction simulation application: For mechanized construction operations such as large equipment installation and ground wire display, the construction personnel apply software system, carry out mechanized construction simulation based on the configured parameters, view the construction process, find construction problems, and optimize the construction plan. Provide a reference basis.

Figure 5. Line wind deflection simulation

5.3 Paperless construction
Preparation of 3D design results: Before construction, the construction personnel call and prepare the 3D design model from the database through the moving segment.

The logical structure of the construction unit model is reorganized. According to the construction requirements, the construction personnel re-divide the logical structure of the design model to adapt the model structure to the construction requirements.

The construction personnel can fully display the entire transmission line and the surrounding environment through mobile devices; and also view the civil engineering, tower three-dimensional
model and attribute information through operations such as translation, rotation, zooming, positioning, and selection.

5.4 Three-dimensional auxiliary design for construction

According to the requirements of the construction of the construction site project department, all the facilities required for the construction of the project department will be modeled in three dimensions, and the construction temporary construction model library will be constructed.

Then, the construction personnel can carry out the construction of the temporary construction facilities according to the three-dimensional construction design plan and the layout plan results. The application steps are as follows.

After the construction of the temporary construction facilities is completed, the layout plan of the temporary construction facilities can be exported. The drawings include the setting positions and the corresponding dimensional standards, together with the size information of all facilities and the corresponding design statistics.

5.5 Construction approach planning and residual soil treatment

Arrival planning: the public road network data, screen the road are read according to the limit width, height limit and limit weight in the road network data, and the path planning work is carried out according to the location of the set construction project department.

Residual soil treatment: The total amount of residual soil treatment is calculated by tower base shape data management and earthwork calculation according to on-site topographic information.
6. **Conclusion and future**

Relying on the achievements of 3D design, mobile internet, Internet of Things and 3D digital technology will be applied to the construction site and further improve the project management safety quality of power grid construction projects. The three-dimensional auxiliary construction application system for power transmission engineering has strengthened the implementation of the whole life cycle management concept of transmission engineering and led the development of the construction field to lean management.

The application of the example shows that the three-dimensional construction application system improves the work efficiency and quality level of the transmission engineering construction process, and realizes the information, automation and three-dimensional visualization of some construction processes. However, the promotion and application of three-dimensional technology requires a long-term, gradual process. It is not only a tool and means, but also a working method and mode of thinking, which will play a good role in promoting the development of the transmission engineering industry.

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References

[1] LI Pan, XIE Fang-yi, LI Hui-juan, SI Hai-qing, LEI Hong-xia. Auxiliary Construction Investigation System of Transmission Lines Project Based on 3D GIS [J]. GEOMATICS & SPATIAL INFORMATION TECHNOLOGY, 2016, 39(8):104-106.

[2] Yu C , Qian Z Z , Yan Z Y . Design and Research of Substation Auxiliary Decision Platform Based on 3D GIS[J]. Electric Power Information & Communication Technology, 2018.

[3] Zhang Fangning. Construction and Research of 3D Visual Construction Management System for Power Grid Engineering [N]. Science and Technology Innovation Herald, 2016(11):81-82.

[4] Luo Zhen. Research on GIS-based three-dimensional digital assistant decision-making application system [D]. Taiyuan University of Science and Technology, 2012.

[5] JIANG Ronga, YAN Ping. Application of 3D Digital the Electricity Network Technique in the Construction Management of Extra High Voltage Engineering[J]. Electric Power Survey & Design | Electr Power Survey Desig, 2007(5):65-68.

[6] Ren Peixiang, Hou Xiaobo,DongJian. Application Research of 3D GIS in the Whole Process of Power Grid Construction Project [C]// Beijing, Hong Kong and Macao Surveying and Mapping Technology Exchange Conference. 2013.

[7] Zheng Xiaoguang,Chen Chi,Wang Ke. 3D High-efficiency and High-precision Modeling for Power Transmission Tower based on All-factor Component Model[J], Guangdong Electric Power, 2017,(30)06,94-97.

[8] MAIXiaoming, CHEN Chi, PENG Xiangyang, ZHANG Boyu, WANG Ke, YANG Bisheng,WANG Rui .3D Visualization Technique of Transmission Line Corridors: System Design and Implementation [J]. ELECTRIC POWER, 2015, 48 (2) :98–103.

[9] WANG Ting-song., MIAO Shuang-xi. Research for Power Line Inspection Based on 3D GIS[J]. GEOMATICS & SPATIAL INFORMATION TECHNOLOGY [J]., 2016 (9) :137–139.

[10]Wang Rusong, Li Jian, Liu Wenxun, Zhao Yuantao, Zhang Yixiu, Zhang Hu, Lin Fang, Zhu Zhenshan. Application of 3D Digital Design in Transmission Lines Projects[J]. ShanXi Electric Power, 2015, 43(8):25-29.

[11] Zhang N , Wang L , Cheng G , et al. The application of 3S in investigation and design of electric power transmission line[C]// International Conference on Consumer Electronics. IEEE, 2014.

[12] XIONG Xiao-guang. Construction and Application of Three-dimensional Digital Design Platform in Transmission Line [J]. Electric Power Survey & Design, 2013(3):66-70.

[13] Liu Wei,Huang Zhao, Li Peng, Li Men, Ding Yan. Summary about System and Framework of Unified Supporting Platform of Big Data for Smart Distribution Grid [J]. TRANSACTIONS OF CHINA ELECTROTECHNICAL SOCIETY, 2014(s1):486-491.

[14] LI Tieding, LIU Wenzun, LIN Fang, LI Jian, WANG Tao. Overall Process Application and Prospects of Digital Design for Transmission Line Projects [J]. Smart Grid, 2016, 4(3):323-327.

[15] Pan Fengping,Zhang Xi, LiFeng,Xie Yijing,Fang Yanjun.Design for Engine of Digital Visual System of 3D virtual Thermal Power Plant[J]. Guangdong Electric Power, 2014(3):1-4.

[16] Gao Miaoxian,Hu Tianshuo. Transmission line design intelligent integrated system [N]. Technology and Economic Guide, 2017(12):26-27.