Application of Three-Dimensional Design in Substation Design

Hailiang Wu*, Lin Xing¹, Zhong Liu¹, Wuchen Zhang¹, Nan Cheng¹, Teng Li¹, Yamin Wang¹ and Wen Zhang¹

¹State Grid Hebei Economic Research Institute, Shijiazhuang, Hebei, 050000, China

*Corresponding author’s e-mail: 463289609@qq.com

Abstract: With the improvement of design requirements and computer technology, the three-dimensional design with multi-professional collaborative design, refined design and engineering digitization as the core, is being popularized and used in the substation engineering design of State Grid Corporation. This paper analyzes concrete measures, conducts benefit analysis of three-dimensional design in engineering design, and discusses the application of three-dimensional design in substation design combining with practical application cases.

1. Introduction

Design, the key in engineering construction, can provide drawings required for engineering construction, strong underlying data information for procurement, operation, maintenance and repair[1], possibility for the extension of value-added design services[2], and also data for creating the full life cycle of projects.

As engineering construction puts higher requirements on design and technology advances, design in the power industry has changed greatly from the traditional two-dimensional (2D) design to three-dimensional (3D) design. 3D design facilitates the collaborative work among electricity, architecture, structure, water-heating and other professions and significantly improve its quality and efficiency through meticulous design[3].

The application of 3D design in substations is now a research focus in design institutes[4][5].

2. Advantages of 3D Design in Engineering

2.1 3D Design Platform

3D design platforms for substations are built with the database of model library and standardization schemes at the core. Through data correlation and sharing and integrated 3D design, collaborative designs in electricity, structure, construction, water-heating and other professions of the same substation can be realized. The model library is set up to store the equipment models and the civil engineering models of substations. These models are constructed according to the State Grid Corporation of China's Technical Guide for 3D Design in Power Transmission and Transformation Engineering Section 1: Substation (Conversion Station) and Modeling Specifications for 3D Design of Substation (Conversion Station). By doing so, all models are unified and standardized and the quality and efficiency of design are improved.
2.2 Collaborative 3D Design
The collaborative 3D design [6] system based on the same 3D design platform and substation engineering model not only improves the efficiency of data exchange among various professions, but also reduces errors and workloads of data exchange and duplication of work to the utmost extent. Specialists in primary, secondary substations and civil engineering of substations are able to design in the same substation engineering model and update the data and model in real time. Any collision and conflict among these professions are presented timely and vividly to avoid errors and omissions in data exchange and collisions of models, improving the efficiency and quality of design effectively.

2.3 Detailed design
The meticulous 3D design makes it possible to carry out collision detection and safety clearance verification in the foundation of buildings and underground pipelines, and to generate construction drawings and automatically keep statistics of engineering workload based on the 3D model. As a result, we can reduce design errors and omissions and the impact of modifying designs on project duration and cost.

2.3.1 Collision check. Carrying out the 3D design with the same model of transformer substation will enable specialized persons to check the collision between foundations of substation, foundations and underground utilities, and underground utilities according to specification requirements and exchange of data. The 3D model can also display the collision to specialized persons so that they can fix the problem quickly and effectively prevent designing errors from happening.

2.3.2 Safety clearance check. We can verify safety clearance by setting parameters to automatically check whether the safety distance between equipment at different voltage levels and the distance between equipment and ground meet the specification requirements and real engineering conditions. When wires in substation are complex and are crowded in a small space, energized equipment and wire will be intersected. Therefore, verification of safety clearance merely based on design paper will be time-consuming and cause high error rates. 3D design is visualized and accurate and can verify safety clearance, which greatly improves the efficiency of spatial design.

2.3.3 Extract 2D drawing. Using 3D designing collaboration technology, designing data and information can be shared and updated in parallel between different drawings. Based on the 3D model, designing files such as 2D plane, graphic and profile drawing, equipment axonometrical drawing, and material reports can be extracted, which not only makes the design file accurate and efficient, but greatly saves the design workload.

2.3.4 Quantity Statistics. 3D model of the substation makes statistics of engineering quantity accurate and easy to be calculated. By setting the range, engineering quantity statistics of the entire substation, areas of power distribution units at different voltage levels or quantity of different specialized lines can be calculated to meet requirements of engineering accuracy and depth at different designing stages.

3. 3D design benefit analysis

3.1 Improving the quality of engineering design
First, we should use 3D design to find the weak points so that we can target at them to improve the quality; second, we should use 3D collaborative design to improve the efficiency of different specialized lines; third, we should use 3D visual design to lift refined design to a higher level.

3.2 Realizing targeted investment of engineering
First, with 3D design, the engineering quantity can be calculated accurately. Information of main
equipment, designing data and material data based on the 3D model of the substation can be automatically counted to make targeted budget estimation; secondly, meticulous and qualified design will save engineering investment; thirdly, calculation and analysis based on 3D model will be more accurate.

3.3 Strengthening engineering safety
Soft and hard collision check and safety clearance verification of 3D design allow designers to avoid errors and omissions in the early stage of engineering design, which can reduce the impact of design changes on construction days and cost and can help engineering management. For example, with accurate and visualized calibration of distance between electrical and gas equipment, designers will produce reasonable designing scheme. With stereoscopic and visualized 3D cable laying, designers will make less construction errors.

3.4 Improve the Quality of Project Construction Management
First, the participating parties can directly grasp the design plan, and improve the construction management efficiency with the assistance of 3D design. Second, the material procurement can automatically extract the material list according to the equipment coding and characteristic parameters of the equipment model. The third is to connect the factors and data produced during the construction process by using the 3D model, achieve 4D dynamic visualization management of the project, and ultimately enables more meticulous management of the construction process.

3.5 To Achieve Whole-Process Application of the Engineering Data
The 3D design platform is equipped with a strong database. First, the business system of the infrastructure and the operation inspection department can extract relevant structured data from the 3D model data. Second, the 3D model can correlate the information and data generated from each stage and each business system, which is quick and convenient. Third, after the 3D design platform is transferred to the operation inspection department, it can support the visual management of operation and maintenance, and satisfy the need for functional development of the 3D model during the operation inspection.

4. The Application of 3D Design in Substation Engineering
Longquan 220kV substation is the first batch of 220kV modular pilot project of China’s state grid. Taking the new project as an example, the specific application of 3D design in substation engineering design process will be discussed.

Firstly, the substation’s unified column grid is established by the civil engineering profession. Next, the substation will perform one conversion. Then, the civil engineering will fixate the reference point on the design platform, and carry out collaborative design work on the substation’s column grid.

The electrical profession establishes the product model according to the equipment drawings provided by the manufacturer shown in figure 1, and assigns values to the equipment parameters of the adopted product model, in order to facilitate further operation and maintenance of the substation. Through the use of 3D design platform with safety clearance verification (show in figure 2), secondary cable automatic laying (show in figure 3), wire tension verification (show in figure 4), lightning protection design and other functions, the platform helps to not only achieve design visualization, but also optimize the overall station layout, and reduce the occurrence of design errors to a large extent.
The civil engineering profession uses 3D design software to generate 3D model of the site through 2D topographic map. The model can accurately simulate the natural terrain and landform where the site is located, besides, the coordinates and the elevation of each point in the model are consistent with the actual natural terrain (show in figure 5). By accurately simulating the natural topography of the site, and considering the location, drainage method, road allowable slope and earthwork balance, etc., the vertical layout of the general plane of the site and the amount of earthwork will then be determined.
Figure 5. Two-dimensional topographic map to establish a three-dimensional site model

Longquan 220kV substation uses 220-A1-1 plan. The 3D design of civil engineering includes: wall and gate, buildings, capacitor foundation, GIS foundation, supporting structure foundation, cable trench, fire pipe network, water supply and drainage pipe network, etc.

Collision detection among all professions is carried out to ensure the quality of design. Collisions among underground pipelines and between pipelines and foundations are adjusted and revised timely to avoid modifying designs in the later part of construction (shown in figure 6), saving both cost and time for project construction.

Figure 6. The capacitor disconnecting switch base collides with the cable trench

After the 3D substation design is completed, we slice the overall 3D substation model to generate the plan, elevation and section of each building and also the electrical power distribution unit diagrams and panel sections (shown in figure 7), which automatically produces equipment parameters and other information. If the master plan is adjusted, accordingly power distribution unit diagrams and panel sections are automatically adjusted (shown in figure 8), significantly reducing design errors and omissions.

Figure 7. Distribution unit room plan
The Longquan 220kV substation project adopts the 3D design method, which the 3D model of the whole substation is shown in Figure 9. Through 3D collaborative design and meticulous design, professions can achieve in-time communication and close cooperation, which will minimize design errors and risks, thus significantly improving design quality and efficiency. Under the 3D collaborative design mode, the design files and 3D models are updated in real time, and the 3D design results can be used for collision check and space clearance verification at any time. Through program optimization and design optimization, the project can solve the design defects that occur in time, and achieve cost reduction, construction period reduction and sustainable development.

The Longquan new project has multiple advantages by employing 3D optimization design. Compared with the 2D design, the total area covered is reduced by 60 m², and the cost by 18,000 yuan; the road area in the station by 21 m², and the cost by 4,200 yuan; the cable trench length by 6 m, and the cost by 3,500 yuan; the grounding materials by 762 m, the cost by 24,000 yuan; the steel used in the construction of building by 5.5t, and the cost by 42,000 yuan. The investment saved totaled 92,000 yuan, accounting for 0.26% of the construction and installation costs of the project.

5. Conclusions
The application of 3D design is a revolution in the field of substation engineering design. Under the 3D collaborative design mode, the design information and 3D model can be updated and interacted in real time, which is beneficial to the optimization and adjustment of the design scheme, and improves the efficiency and quality of the engineering design. Through the visualized 3D model and the meticulous design results provided by the 3D design, the data integration application is formed, and the multi-link sharing of power grid engineering management is achieved, which helps to improve engineering construction and production operation and maintenance management. This has laid a solid foundation for building a digital power grid and serving full life cycle management of the project.

References
[1] Chen jing. (2013) Application Research of 3D Collaborative Design in Intelligent Substation Design. Electrotechnical Application, S1:539-544.
[2] Ran Ruijiang. (2012) Discussion on the Application of Bentley Software in Substation 3D Digitalization Design. China Electric Power(Technology Edition):83-86.

[3] Qie Xin, Qi LiZhong,Hu Junhui. (2012) Application of 3D digital technology in power transmission and transformation engineering.Power Grids and Clean Energy,28(11):23-26.

[4] Li Zhihai. (2015) Research on digital 3D substation design technology. Electrical Engineering,16(11):83-86.

[5] Zhao yayuan,Xu Wanjun,Han Yongxing,etc. (2014) Development and application of intelligent substation 3d design in shaanxi institute. Electric Power Survey & Design,4:8-9.

[6] Xiang Ling,Shao Junwei,Tan Hailan,etc. (2012) 3d collaborative design of smart substation. China Electric Power,11:454-459.