Research on General Model Library Framework of Substation Engineering

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Abstract. The data format of the current substation 3D design results is inconsistent, and the data of different software platforms is not connected. For the problem of these, this paper analyzes the current status and mainstream data format of 3D design of substation comprehensively, and establishes a standard database framework that is suitable for substation engineering, which can achieve cross-platform data integration and utilization, and provide a technical support for the formation of State Grid Corporation’s substation 3D design standardization model library.

1. Introduction

In order to implement the development strategy of building a “one strong and three excellent” modern company, State Grid Corporation proposed an informational development plan of “building a digital power grid, building an information enterprise, and providing strong support for the construction of modern companies”. In order to implement the development strategy of building a “one strong and three excellent” modern company, State Grid Corporation proposed an informational development plan of “building a digital power grid, building an information enterprise, and providing strong support for the construction of modern companies”. State Grid Corporation attaches great importance to 3D design research and practice. At present, it has clearly proposed three-dimensional design for power transmission and transformation projects.

The 3D design results are transferred to the engineering data center, which is accumulating and forming a large grid basic database.

The basic database provides important supports for statistical analysis and intelligent business management. However, at present, the source of these data comes from different commercial software and there is no unified data format between the platforms, and they cannot communicate with each other. As a result, the three-dimensional results cannot be recognized and utilized by each other, which may cause the inconsistent format and definition of the basic data and hidden dangers for later applications.

2. Overview of 3D Design Software Platform for Substation

In 2017, State Grid Corporation conducted extensive researches on various design institutes across the country. According to the survey data of several provinces and cities (incomplete), the software usage of the professional 3D software platform of the substation is summarized.
According to the table above at present, most domestic design institutes adopt two major platforms in the mainstream of three-dimensional digital design of substation. One is the STD-R platform developed by Bochao based on AutoCAD and Revit software, and the other is a series of solutions developed by Bentley based on Microstation software. Analysis of file formats and supported file formats of Bochao and Bentley platforms shows as follow.

| S/N | Subject      | 3D design platform | percentage |
|-----|--------------|--------------------|------------|
| 1   | primary electrical | Bentley substation | 50%        |
|     |              | STD                | 29.1%      |
|     |              | Revit              | 12.5%      |
|     |              | TianZheng Electrical | 4.2%     |
|     |              | HaoChen CAD        | 4.2%       |
| 2   | secondary    | Bentley promis-e   | 42.9%      |
|     |              | STD                | 21.4%      |
|     |              | Revit              | 7.14%      |
|     |              | Ou Lian            | 7.14%      |
|     |              | TianZheng Electrical | 7.14%   |
|     |              | HaoChen CAD        | 7.14%      |
|     |              | XD-ITDS            | 7.14%      |
| 3   | general layout | Bentley Geopak     | 42.8%      |
|     |              | STD                | 28.6%      |
|     |              | Bentley ABD        | 14.3%      |
|     |              | HongYe             | 14.3%      |
| 4   | architecture | Bentley ABD        | 43.5%      |
|     |              | Revit              | 17.5%      |
|     |              | STD                | 13.1%      |
|     |              | TianZheng Electrical | 8.7%    |
|     |              | HaoChen CAD        | 4.3%       |
|     |              | PKPM               | 4.3%       |
|     |              | CASS               | 4.3%       |
|     |              | Explorer           | 4.3%       |
| 5   | structure    | Bentley ABD        | 28.5%      |
|     |              | Revit              | 19%        |
|     |              | STD                | 9.5%       |
|     |              | PKPM               | 14.3%      |
|     |              | TianZheng Electrical | 4.8%   |
|     |              | HaoChen CAD        | 4.8%       |
|     |              | CASS               | 4.8%       |
|     |              | Explorer           | 9.5%       |
|     |              | Straightening tool box | 4.8%  |
|     |              | Component calculation | 4.8%   |
Table 2. Software Platform Support Formats

| Feature Item | Autodesk Revit | Bentley Microstation |
|--------------|---------------|----------------------|
| File Extension | *.rvt         | *.dgn                |
| Import/Export | DXF/DWG(Autodesk Products)File Formats Supported: DWG, DWF, DXF, IFC, SAT, STL, SKP(Sketchup) , AVI(video) , ODBC, gbXML. | DGN(Integration of various file types and different file types):DGN, DWG, DXF, PDF, STEP, IGES, STL, CEL, IFC, DGNLIB, S, H, RDL(RAM), 3DS(wireframe) , OBJ, SKP (sketchup). |

The original file formats of the two platforms are rvt and dgn, respectively. The underlying data formats of the two platforms are not uniform. Using the original data format directly will cause the inconsistent data formats in the data center, affecting later analysis statistics and utilization. Analyze the data formats that can be exported by the two platforms, including DWG, DWF, DXF, IFC, STL. The DWG, DWF, and DXF formats are mainly used in a two-dimensional platform, while the STL format is a surface model and does not have attribute information. The IFC format is an internationally accepted industry-based classification standard, which defines 8 specific areas of expertise, such as construction, structural analysis, and electrical field. It has good versatility and can be used as the basis for data interoperability. It has a good versatility and can be used as the basis of data interoperability.

3. Analysis of IFC Data Standard
IFC is the most common form for data interaction of international BIM. The civil construction of substation can use IFC as an interactive form. However, the electrical part clearly indicates its scope of application in the IFC: the definition of electrical part includes power distribution and lighting, communication, protection, signal, controller, audio and video equipment and cable, electrical circuit interface, ..., voltage level is 12V (AC / DC) ~1000V (AC) or 1500V (DC). Oher voltage levels of electrical parts are not specifically provided, so IFC cannot be applied to high voltage electrical equipment in power transmission and transformation projects. Therefore, for the high voltage part of the substation where IFC is not clear, it is necessary to consider a new method to define.

4. Research of GIM Data Standard
For the interactive format of the high-voltage electrical part model which is not covered by IFC, a new data standard framework should be defined, which we called GIM(grid information model). The 3D design model framework consists of a four-layer structure:
Property sets, component classes, physical models, logical models, engineering models. The purpose is to solve the problem of sharing and intercommunication of 3D design model data, and provide an interactive method of power transmission and transformation engineering model based on 3D design.

A power transmission and transformation engineering model interaction method based on three-dimensional design, including the following parts: The standard format of the 3D design model of power transmission and transformation engineering includes file header, index domain and storage domain. The file header stores metadata information of the model file, including file identifier, file name, creation time, version number, and the version number. The index domain stores the directory structure information of the model file, which is composed of the root directory and four levels of subdirectories. The four-level subdirectory is the index address of the corresponding data in the storage domain. And data in the storage domain can be retrieved from the catalog.

The storage domain stores the data entities of the model. The data is contiguously stored in blocks according to the four levels of subdirectories of the index domain.

The data stored in by the standard format file includes: geometric model unit (*.mod), combined model (*.phm), physical model (*.dev), logical model (*.sch), engineering model (*.cbm), and attributes. Information(*.fam). Standard format files are stored in a four-layer file structure: CBM, DEV, PHM, MOD. The file uses a GUID as a unique identifier. Standard format files establish relationships between levels by reference.
The geometric model unit (*.mod) is composed of multiple basic primitives and parametric models. The basic primitives are a series of simple basic geometry (such as cubes, cylinders, cones, etc.) that are required to form a solid model.

The combined model (*.phm) consists of multiple geometric model elements, mesh models, and attributes (*.fam). The combined model includes geometric model elements, references to mesh models, and corresponding spatial transformation matrices. A composite model can make a peer reference, but it cannot reference itself.

The logical model (*.sch) consists of graphical symbols and their associated relationships, including drawing data, component symbol positioning data, encoding and attribute parameters, and connecting lines. Logical models can be peer-referenced, but they cannot reference themselves.

The physical model (*.dev) consists of a combined model (*.phm) and a physical model attribute (*.fam). The physical model attribute (*.fam) includes parameters such as name and encoding. The physical model (*.dev) can make peer references, but not itself.

The manufacturing model refers to the lofting model of the equipment manufacturing model and the building structure, and the query and visualization can be realized by attaching files. The device manufacturing model format is *.stl, *.stp, *.x_t, *.sat, *.dxf, stored in the DEV folder. The layout model of the building structure (frame, steel structure, fabricated wall, etc.) is recommended as *.ifc, *.stl, *.dxf, and stored in the DEV folder. The file path of the manufacturing model is stored in the properties file (*.fam) with a relative path.

The engineering model (*.cbm) consists of a physical model (*.dev), a logical model (*.sch), and an engineering attribute (*.fam). The project properties (*.fam) include parameters such as name, voltage level, and encoding. The engineering model has only one origin coordinate. The physical models of the composite engineering model are spatially transformed relative to the origin of the coordinates. The engineering model (*.cbm) can be referenced at the same level, but it cannot reference itself.

The project model list (project.cbm) file contains project name, project geographic coordinates (substation (conversion station) or tower), voltage level, and reference to the engineering model (*.cbm) file.

The data stored in the standard format file includes: geometric model unit (*.mod), combined model (*.phm), physical model (*.dev), logical model (*.sch), engineering model (*.cbm), and attributes. Information (*.fam). Standard format files are stored in four directory structures, as shown in Figure 1.

![Figure 1. Organization Structure of 3D Design Model File for Power Transmission and Transformation Project](image)

There is a reference relationship between the files contained in each level of the standard format file, as shown in Figure 2.
5. General Model Library Framework Construction

In summary, the overall framework of the substation general model library consists of an electrical part and a civil construction part. The electrical device uses the basic primitive combination method to construct the solid three-dimensional model, and interacts in the GIM format. The civil construction model uses the IFC format to interact, and for the special shape, the surface model is used for interaction. The overall framework structure of the substation general model library is shown in Figure 3.

6. Summary

Through combing the modelling methods and attribute information of various facilities in the substation, this study establishes a framework system scheme that contains State Grid Corporation’s 3D Design General Model Standard Database which contains a three-dimensional general model including basic primitives, parametric models and main equipment of 35kV~750kV substation. It can manage and maintain all kinds of 3D model data.

The research results have technical support for the formation of the substation 3D design standardization model library of State Grid Corporation.

The application of the example shows that the research results have a technical support for the formation of the substation three-dimensional design standardization model library of the State Grid Corporation. 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 an essential role in promoting the development of the transmission engineering industry.

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