Fineness Standard and Implementation Method of 3D Model of Electrical Equipment in Substation (Converter Station)

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Abstract. In order to solve the problem of inconsistent modeling depth and uneven model granularity in the 3D modeling process of power grid engineering, this paper analyzes the fineness requirements of 3D models at all stages of engineering. Referring to the LOD rule of the US National BIM Standard, three-dimensional model fineness guidance for electrical equipment in substations (commutation stations) is developed and the model fineness is divided into two fineness levels, including the general model and the product model. The feasibility of the guidance is verified by actual engineering.

1. Introduction

As the source of power grid construction, the design of power transmission and transformation is an important part of life cycle data creation for power system. It has the ability to integrate a variety of information to maintain the uniqueness and correctness. State Grid Corporation attaches great importance to 3D design research and practice. At present, it has clearly proposed that three-dimensional design should be used for power transmission and transformation projects.

3D design is a design technology based on three-dimensional information model with using network, database, graphics processing and other technologies, combined with multi-professional, multi-task collaborative design. As the most important design result in the whole life cycle of the project, in addition to its own design value, the 3D model can provide important data carriers for the data application in the subsequent stages of engineering construction.

Therefore, the construction of the three-dimensional model is not only the basis of engineering digital construction, but also an important guarantee for maintaining the quality of digital products. Therefore, the construction of the three-dimensional model is not only the basis of engineering digital construction, but also an important guarantee for maintaining the quality of digital products. However, the current three-dimensional design of power transmission and transformation engineering lacks corresponding modeling standards and guidelines, and it is difficult to divide the modeling fineness of each stage accurately. When each unit is working on three-dimensional design, because the design range and depth is inconsistent and the 3D modeling level and model granularity are different, it is difficult to guarantee the accuracy and depth of engineering design, and the practical application of these design results is greatly limited.

To solve the problems above, this paper develops a set of modeling criteria for modeling depth and attributes of 3D models from studies on the requirements of key components, key dimensions, key parameters based on the analysis of design, construction and operation process.
2. Precision Requirements of 3D Models

2.1. The Preliminary Design Stage
The main goal of the preliminary design stage is to determine the appropriate design layout. The geometrical fineness of the model needs to consider the shape of the electrical equipment, the space in which the live part is connected to the main structure, the fire distance, and the space for running the maintenance passage. For example, the projection of the transformer mailbox on the ground will affect the size of the oil pool. The height and angle of the transformer bushing will affect the charging distance check of the lead wire. The position and height of the main transformer oil pillow affect the size of the oil pool and the height of the firewall. The size of the external body must be able to cover the current manufacturer's requirements. In addition, considering that the components in the equipment may be managed, maintained, and replaced during the post-operation and maintenance process, the model also needs to contain components with independent functions. Taking the transformer as an example, in addition to the main body, equipment modeling, such as mounting base, bushing (ceramic bottle), terminal block, cooler, pressure-proof shielding device, bushing, also need to be considered. Equipment model attribute accuracy is mainly engineering basic parameters and design basic parameters. For example, the type, voltage and cooling mode of the transformer will affect the material statistics. The material coding property of the transformer will affect the subsequent material bidding. The physical ID number attribute of the transformer will affect the subsequent operation and maintenance. Therefore, as the design depth increases, the geometric fineness and attribute fineness requirements of the model will gradually deepen.

2.2. Parts of Construction Drawing whose Geometry Fineness Needs to be Deepened
- Position and angle of the bushing terminal block: affect check of electrical distance.
- Direction and angle of the terminal block: It affects the angle of the lead wire.
- Fuel tank parts (including oil pillow, oil pipe and oil-filled casing): affect the size of the oil pool.
- Outer contour of the metal part of body: affect the charging-distance check of the casing and the lead wire.
- Civil construction interface: affect the construction of civil engineering foundations and embedded parts and later operation and maintenance.
- Grounding device of Core clamp: affect construction and maintenance.
- Pressure release device: affect construction and operation and maintenance.
- Jack position: affecting construction and operation and maintenance.
- Lifting lug position: affecting construction and operation and maintenance.

2.3. Parts of Construction Drawing whose Attributes Fineness Needs to be Deepened
- Transformer weight: affect the analysis of structural force calculation.
- Transformer model: affect operation.
- Transformer manufacturer: affect operation.
- Size and material of terminal board: affect the choice of wire fittings.

According to this method, the modeling geometrical fineness and attribute fineness of the 3D models of 15 categories which include 400 main equipments of 35kV~0kV substation, including transformers, circuit breakers, disconnectors, earthing switches, surge arresters, voltage transformers, current transformers, capacitors, reactors, resistors, GIS, post insulators, switchgear, hard busbars, wall bushings, are combed to form the modeling requirements.

3. Hierarchy of Model Fineness
At present, many countries have specified the level of detail of the construction engineering information model. For example, the US LOD grading strategy explicitly specifies the integrity of the model components in the BIM model expected during different phases of the construction life cycle, which has been widely recognized. The "Building Information Model Design Delivery Standard" issued by the Ministry of Housing and Urban-Rural Development also stipulates the model fineness, information granularity, modeling accuracy, geometric expression accuracy, information depth,
deliverables, expression methods, and Collaborative requirements of the building information model. However, in the field of power grids, it is still blank.

3.1. **US National BIM Standard (NBIMS)**

The National BIM Standard (NBIMS) edited by the National Academy of Building Sciences (NIBS), the LOD (Level of Development) is used to refer to the level of completeness expected by the model components in the BIM model during different stages of the construction life cycle. The fineness of the building information model, information granularity, modeling accuracy, geometric expression accuracy, information depth, deliverables, expression methods, and coordination requirements are specified. Five LODs from 100 to 500 are defined, as shown in Table 1.

| Precision grade                  | Abbreviation |
|----------------------------------|--------------|
| Level of Detail 100              | LOD100       |
| Level of Detail 200              | LOD200       |
| Level of Detail 300              | LOD300       |
| Level of Detail 400              | LOD400       |
| Level of Detail 500              | LOD500       |

This grading method stipulates that the attribute fineness of the information model is described by "information granularity", and the geometric fineness of the information model is described by "modeling geometric fineness". For example, the information granularity of the "physical characteristics" in the building attribute information is as shown in Table 2:

| Building property information   | LOD100 | LOD200 | LOD300 | LOD400 | LOD500 | Remarks (code) |
|---------------------------------|--------|--------|--------|--------|--------|----------------|
| physical feature                |        |        |        |        |        |                |
| Quantity attribute              | △       | △      | ▲      | ▲      | ▲      | 05.10.00       |
| Shape attribute                 | △       | △      | ▲      | ▲      | ▲      | 05.13.00       |
| One-dimensional size            | △       | △      | ▲      | ▲      | ▲      | 05.16.00       |
| Two-dimensional size            | △       | △      | ▲      | ▲      | ▲      | 05.19.00       |
| Space size                      | -       | -      | ▲      | ▲      | ▲      | 05.23.00       |
| Ratio                           | -       | -      | △      | ▲      | ▲      | 05.26.00       |

Note: “▲” in the table indicates the information that should be available, “△” indicates the information that should be available, and “-” indicates the information that may not be available.

Similarly, the model's "modeling geometry fineness" is specified by the LOD level. For example, in LOD300, the model fineness rules for design sites, roads, and municipalities are shown in Table 3.

| Site of design                   | The contour height should be 1m. The relationship between the filling and excavation of the current site should be observed in the cutaway view. |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Road and municipal               | Roads and curbs. For the necessary municipal engineering pipelines, the modeling geometry accuracy should be 100mm. |
It is well known that the accuracy of the model and the speed of the computer cannot be met at the same time. The standard believes that lower modeling precision should be adopted on the premise of meeting the project requirements.

3.2. Substation Electrical Equipment Model Fineness Regulations

Referring to the US NBIMS hierarchical division method and the sub-station (conversion station) electrical equipment three-dimensional model fineness division method, under the premise of taking into account the requirements of model accuracy and the efficiency of computer operation in each engineering stage, according to the preliminary design stage and the construction drawing design stage, the three-dimensional model is divided into two fineness levels: the general model and the product model.

This provision still refers to the basic principle of NBIMS, that is, “Under meeting the needs of the project, Lower modeling fineness should be used.” At the same time, the attribute fineness table and the geometric fineness table are respectively used to represent the attribute fineness and geometric fineness of the three-dimensional model.

Table 4. Attributes Precision of Oil-immersed Transformer 3D Model

| parameter name            | Data type | unit | example | General model | Product model |
|---------------------------|-----------|------|---------|---------------|--------------|
| name                      | Character | -    |         |               | √            |
| Manufacturer              | Character | -    |         |               | √            |
| Type                      | Character | -    |         |               | √            |
| Material                  | Character | -    |         |               | √            |
| Model specification       | Character | -    |         |               | √            |
| Phase category            | Character | -    |         |               | √            |
| Rated current             | Float     | A    |         |               | √            |
| Insulation level          | Float     | kV   |         | √             | √            |
| Partial discharge level   | Float     | pC   |         | √             | √            |
| tanδ                      | Float     | %    |         | √             | √            |
| capacitance               | Float     | pF   |         |               | √            |
| Bending withstand load    | Float     | kN   |         | √             | √            |
| Effective creepage        | Float     | mm   |         | √             | √            |
| Dry arcing distance       | Float     | mm   |         | √             | √            |
Table 5. Geometric Precision of Oil-immersed Transformer 3D Model

| Types              | Device Name                        | Modeling content       | Basic primitive requirements | special requirements | Defined as a unit? | General model | Product model |
|--------------------|------------------------------------|------------------------|------------------------------|----------------------|-------------------|---------------|---------------|
| Substation equipment | Oil immersed transformer          | Pressure release device | Column, cuboid              | -                    | ✓                 | ✓             | ✓             |
|                    |                                    | Oil level thermostat   | Column, cuboid              | ✓                    | ✓                 | ✓             | ✓             |
|                    |                                    | Moisture absorber (if any) | Column, cuboid              | ✓                    | ✓                 | ✓             | ✓             |
|                    |                                    | Core (clamp) lead-out grounding device | Column, cuboid | ✓ | ✓ | ✓ | ✓ |
|                    |                                    | Oil intake             | Column, cuboid              | ✓                    |                   | ✓             | ✓             |
|                    |                                    | Civil interface        | Column, cuboid              |                      | ✓                 | ✓             | ✓             |
|                    |                                    | Mounting bolt of equipment base and civil foundation | Column, cuboid, Positive polyhedron | - | - | - | ✓ |

It can be seen from the two tables above that the specification divides the geometric fineness and attribute fineness of the three-dimensional model into two levels of “general model” and “product model”, which provides guiding opinions for the three-dimensional modeling work.

4. Application
In this paper, taking the medium-pressure bushing in the 500kV transformer model as an example, the three-dimensional modeling is carried out with reference to the fineness regulations formulated above. The general model stage and the product model stage of the geometric fineness have obvious fineness differences, as shown in Fig. 1 and 2 is shown.

Figure 1. General Model in Preliminary Design
5. Conclusion

Based on the analysis of the requirements of different design stages, combined with the characteristics of construction and operation, guideline standards of 3D model modeling geometric fineness and attribute fineness have been formed from the studies on the requirements of geometric fineness and attribute fineness. It could satisfy the model at different design stages according to the requirements of using, and the model is refined and differentiated to improve the model utilization and work efficiency.

6. References

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