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Research and Development of 3D Module Design System in Nuclear Power Engineering

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ABSTRACT

In order to meet the requirement of independent research and development of modular technology in nuclear power project, a set of convenient and efficient 3D module design system is supplied to the designer with the support of CPR1000 and on the basis of module 3D design system researched and developed by PDMS 3D cooperative design platform. The function and applying effect of 3D module design system can be referred to the research of the second function of PDMS 3D cooperative design platform.

1. INTRODUCTION

Modular design and construction technology is one of the important features of the 3rd Generation nuclear power plant. The engineering experience in other countries, especially in Japan, has verified that the application of modular design and construction technology in NPP engineering can shorten construction period, improve project quality and reduce cost. At present, there are cases of modular construction in Chinese CPR1000 and NPP of other reactors under construction and in operation, such as the construction of part of the dome of reactor building, and the four NP groups in China have researched it to some degree as well. Nevertheless, the systematic R&D of modular design and construction technology in NP engineering and its scale application is still falling behind. The 3rd generation nuclear power demonstration projects of AP1000 with modular design have been started construction in Sanmen and Haiyang. The core technology of AP1000 modular design is owned by the Westinghouse Company, and the design knowhow of modules is not included in the scope of technology transfer. Therefore, it is important to develop the 3D module design system with independent property right and applicable to the situation in China, and then supply the designers with a set of convenient and efficient 3D module design system as the strong support to design.

At present, CNPEC (China Nuclear Power Engineering Co., Ltd.) has set up a fairly complete 3D cooperative design platform to carry out cooperative design among disciplines in the design of CPR1000 NP project. As a result, abundant mature applicable experience has been accumulated. Applying PDMS 3D cooperative design platform to carry out modular design: 1) 3D model of power station in normal design flow can be referred to directly without re-constructing independent 3D model for the module, thus the modeling work can be reduced efficiently; 2) The visible cooperative design among disciplines and the function of model impacting check can bring convenience to modular design as well; 3) PDMS 3D cooperative design platform can serve as the integrated platform to supply layout data to each module, yet itself does not have module design function.

2. FRAMEWORK OF 3D MODULE DESIGN SYSTEM

There is no modular concept in the original design of CPR1000 NP project, so neither modular design has been considered in the establishment of 3D model of the plant, nor does PDMS 3D cooperative design platform have module design function. As a result, it is difficult to carry out modular design on PDMS 3D cooperative platform directly. By making full use of the design and management function of the platform and carrying out the secondary development in module design function, the 3D module design system is developed. The 3D module design system takes the highly regularized 3D layout model as its core, carries out cooperative design among

disciplines and fully reflects the design concept of taking 3D model data as the core. Fig.1 shows the framework of 3D module design system.

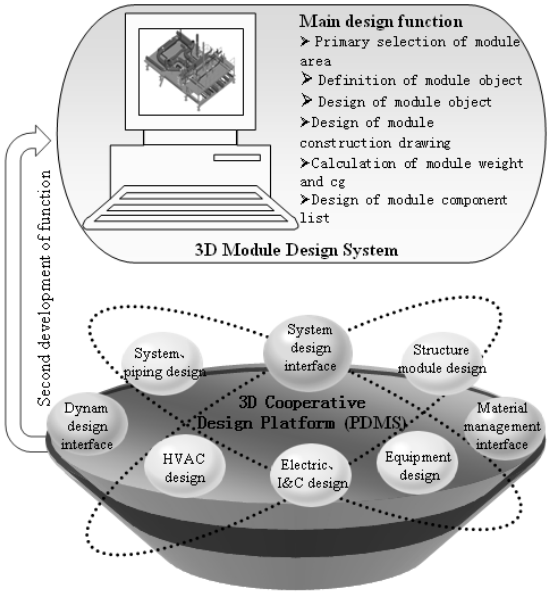

Fig.1: R&D frame of 3D module design system

3. CONTENT OF 3D MODULE DESIGN

The modular construction is to design some zone of the plant structure and (or) system items of nuclear power station designed as a single integrated product(module), then transport the product to the construction site after manufactured in the factory and delivered to the location via the use of integral hoisting systems.

The modular design in NP engineering is a part of engineering design. Fig.2 shows the main contents of engineering design and module 3D design in NP engineering. Where: 1)primary selection of module zone; 2) definition of module object; 3) design of module object; 4) design of module construction drawing are the main contents of module 3D design, and the main functions of 3D module design system are developed on the basis of the above design activities and the requirement of functions.

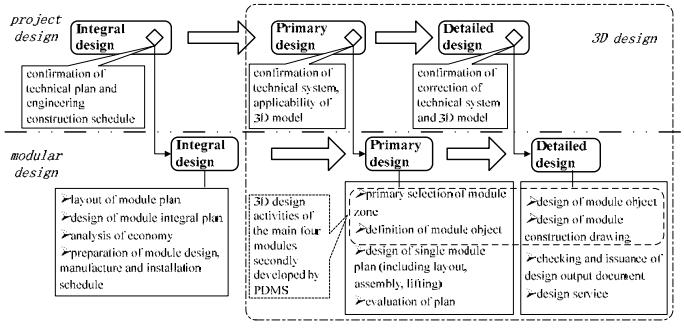

Fig.2: Relation between module design and engineering design

4. MAIN FUNCTIONS OF 3D MODULE DESIGN SYSTEM [1]

4.1 PRIMARY SELECTION OF MODULE ZONE

Module zone means the primarily selected zone suitable for modular construction in primary phase of NPP modular design to shorten construction period, improve quality and reduce cost, which is based on the select principles of module range.

The primary selection of module zone can define the spatial range of module zone in primarily designed NPP 3D model, show the spatial zone for modular design directly, and thus make the designers of all disciplines understand the distribution of module zones and supply information about module space range. The definition of module range shall be as correct as possible to minimize the effort required to define the module object.

4.2 DEFINITION OF MODULE OBJECT

The definition of module object is mainly to select the objects for modular design from the primarily selected module zone, and distinguish the modularized model from non-modularized model in module zone. The modularized models in primary period of modular design mainly include equipment, pipeline, cable tray, HVAC, steel structure, support and hanger, etc. In the mid-late period of modular design, temporary support and hanger, temporary steel structure, newly constructed steel structure, newly constructed support and hanger and temporary pipeline required by installation and transportation of module are included as well.

To make it convenient for modular design, 3D module design system divides 3D models into several classifications according to disciplines (equipment, pipeline, electrics, HVAC, structure, etc.), confirm the basic component types of each classification at the same time, and then carry out modular design type to type. Fig.3 shows the functional interface of definition of module object.

Fig.3: Functional interface of definition of module object

4.3 DESIGN OF MODULE OBJECT

Design of module object means the work done to module 3D model, which includes design optimization (such as integral optimization of support and hanger), welding spot made to order, modeling of new steel structure and support, modeling of temporary steel structure and support, etc., and the necessary adjustment to the module marking properties of 3D model as well.

4.3.1 Design of welding spot

There are just factory prefabricated welding spot and on-site welding spot in PDMS software, while module factory welding spot and module on-site welding spot shall be added in modular design. When carrying out module design on PDMS platform, the original on-site welding spots of PDMS shall be applied for modeling of module factory welding spot, on-site welding spot and module on-site welding spot, while the modeling mode of factory prefabricated welding spot will not change. Module factory welding spot and module on-site welding spot can be distinguished through setting WLDP (welding mark: factory welding (A), on-site welding (M), module factory welding (W) and module on-site welding (F)) properties of welding spot. Fig.4 shows the classification of welding spots.

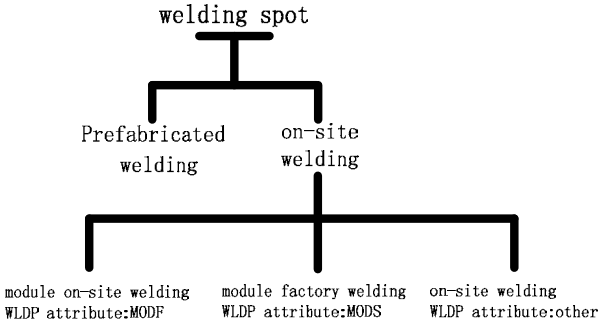

Fig.4: Classification of welding spots in modular design

4.3.2 Model associating mode

Instead of being processed on the basis of the original model, a SITE (model data zone) management layer, which is called as module copy model SITE, is established for each module in the design optimization to model in modular design. The defined main objects of model are copied into the relevant module copy model SITE according to their classifications. After a series of design activities such as optimized design and verification, the design result can be returned to the original model when the design of module model has been finished and confirmed. Fig.5 shows the data layer structure of module copy model SITE.

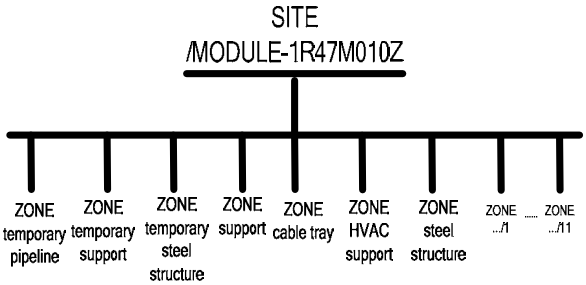

Fig.5: Data layer structure of module copy model SITE

Fig.6 shows the relationship among defined data of module object, original 3D model and module copy model. The association among the models must be checked periodically in different phases of design to ensure the correction of module design.

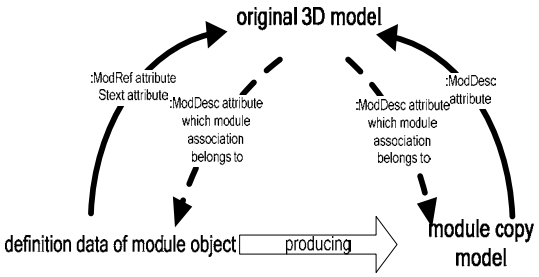

Fig.6: Relationship among defined data of module object, original 3D model and module copy model

4.4 DESIGN OF MODULE CONSTRUCTION DRAWING

4.4.1 Design of pipeline construction drawing

Pipeline construction drawing (called as pipeline 3D drawing, ISO drawing also) will be applied to prefabrication factory, module prefabrication factory and installation site after modular design. 3D Module design system can finish pipeline construction drawing with the functions of PDMS platform: Design module (pipeline model design), Spooler module (sections of pipe model design), IsoDraft module(pipeline 3D drawing generation) and AutoCad software (automatic modification).

4.4.2 Design of module support and hanger drawing

On the basis of module 3D model, support and hanger drawing applies draft module of PDMS 3D cooperative platform and finishes support and hanger drawing according to requirement to meet the design demand.

4.4.3 Design of module assembly drawing

Module assembly drawing is added for the modular design, providing guidance for the module assembly in module factory and the on-site installation. These drawings are generated by using the Draft module of the PDMS 3D cooperative platform. In order to meet the requirements for generation of module assembly drawings, customization is taken into consideration, and appropriate development of the drawing generation tools is performed.

4.5 CALCULATION OF MODULE WEIGHT AND GRAVITY CENTER

The calculating function of module weight and gravity center can calculate and export the weight and gravity center of the module according to its 3D model data, which can be applied by the design of module lifting point and module transportation.

Formula 1 is the calculation method of gravity center.

$$\begin{cases} x = \dfrac{\sum m_i x_i}{\sum m_i} \\ y = \dfrac{\sum m_i y_i}{\sum m_i} \\ z = \dfrac{\sum m_i z_i}{\sum m_i} \end{cases} \qquad \text{Formula 1}$$

In the above formula, x, y, z are coordinate vectors of module gravity center, mi is the weight of module object i, xi, yi, zi are the cg coordinate vectors of module object I respectively.

4.6 DESIGN OF MODULE COMPONENTS LIST

The module components list illustrate the information such as module components and the name, physical property and supply location of the components. The components mainly involve large pipe, small pipe, temporary large and small pipe, valve, permanent and temporary steel structure, permanent and temporary support and hanger, equipment, HVAC, pipeline, cable tray and electrical support, etc. The 3D module design system can realize the automatic generation of module components list in real time.

5. RULES OF 3D MODEL DESIGN

User defined attributes shall be added to some components of special types in 3D model before modular design. At the same time, 3D modular design relies on modeling rules of 3D model with tight regulation as well.

5.1 SETUP OF USER DEFINED ATTRIBUTES

Some user defined attributes shall be added to PDMS 3D model because of modular design. Seen in table 1.

Table 1 User defined attributes of modular design (UDA)

Type of PDMS component	Title of attribute	Type of attribute	Explanation
TEXT	:ModRef	ref type	Associate to modularized model
EQUI BRAN FLOOR WALL GWALL STWALL SCREED SCTN SUBS GENSEC PANE SBFR STRU	:ModDesc	Character string type	Description with fixed format to distinguish whether it is modularized model or not
	:ModType	Real number type	Explain the classification of modularized design model

Note: TEXT (text data node); ModRef (custom attribute); Stext(sub-text data node); ModDesc (custom attribute, belonged to module description); ModType (type of module); EQUI, BRAN, FLOOR, WALL, GWALL, STWALL, SCREED, SCTN, SUBS, GENSEC, PANE, SBFR, STRU (classification of components in 3D database).

5.2 MODELING RULES OF CPR1000 3D MODEL

3D models of different disciplines in PDMS are distinguished by different ZONE (model data zone). Attribute of the type is set in the attributes of ZONE. Distinguishing the original models of each discipline in modular design shall also follow this rule. Modeling of 3D model which corresponds to basic type shall follow 3D Modeling Rules of Module Design to ensure the consistency between the layer structure of newly added items because of module design and the layer structure of PDMS 3D cooperative design platform.

6. DESIGN EXAMPLE

3D Module design system has processed application test in two design projects and made optimization to some functions. The functional requirement of engineering module design has been met and the effect is good.

Fig.7 is the 3D model of a project module designed by 3D module design system. The exported module component list, module assembly drawing and all kinds of construction drawings of the module meet the requirement of both project and custom.

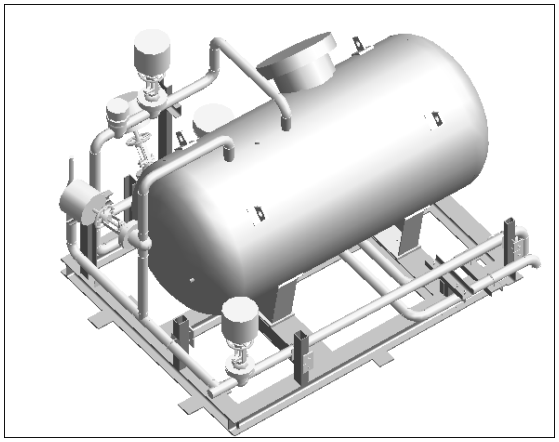

Fig.7: 3D model of a project module design

7. CONCLUSION

(1) The 3D module design system researched and developed on the basis of PDMS 3D cooperative design platform supplies a set of convenient and efficient design implements to the modular design of CPR1000 NPP project, and realizes the cooperative design among disciplines of both module and non-module in the same design platform;

(2) The R&D of this system is also significant to improve 3D design capability of PDMS 3D cooperative design platform, helps the design concept of NP project transfer to taking 3D model as its core;

(3) 3D module design system of NP project researched and developed on the basis of CPR1000 NPP is quite applicable and extendable, it can meet the engineering design requirement of new project with small modification to applicability according to different projects or reactors;

(4) The following R&D of NP project 3D module design system will aim to the field of module design, module fabrication and installation, thus realize the total share of module design data and the paperless drawing.

ACRONYMS

3D: three-dimensional
CPR: China Pressurized Reactor
PDMS: Plant Design Management System
NPP: Nuclear Power Plant
NP: Nuclear Power
R&D: Research &Development
AP: Advanced Passive pressurized water reactor
HVAC: Heating, Ventilating and Air Conditioning
ISO: Isometric

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