Key Technology of Integrated Assembly Construction of Whole Process of Building Electromechanical Project

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Abstract. The prefabricated construction of building electromechanical system is studied. With the whole construction process as the main line, the methods of software and hardware development, numerical simulation and technological innovation are adopted to realize the uniqueness of module orientation, the rapidity and rationality of module design, the automation of factory prefabrication and the high efficiency of prefabricated construction. Based on the self-developed collaborative management platform adapted to electromechanical modular construction, the construction links, construction elements, and participating units are connected in series, realizing the information and integrated management of the construction process, improving the construction efficiency and construction quality, and promoting the development of building electromechanical assembly technology.

Keywords: BIM, information coding, module design, factory prefabrication, assembly construction.

1 Introduction

At present, China's construction industry is still an extensive labor-intensive industry, and the organization, implementation mode and production mode of construction projects are backward. It is necessary to accelerate the industrialization and informatization of the construction industry, and to realize the transformation and upgrading of the construction industry[1-3]. The main measure to promote the modernization of the construction industry is to promote smart and prefabricated buildings. At present, prefabricated buildings have made some achievements in structural system, standardized design of concrete parts, construction of prefabricated processing plants, and on-site assembly and installation technology. However, the assembly and construction of electromechanical system is relatively lagging behind, which restricts the further development of prefabricated buildings.

Ye et al. conducted a research on assembly construction technology for building structures at the theoretical level, but lacked practical application verification[4]. China

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Construction Third Engineering Bureau has conducted research on the modular production and integrated delivery of building machinery and electronics in the software level, but there is a lack of key hardware facilities and technology[5]. In general, the construction and production of electromechanical system is mainly based on the traditional mode, with only a few practical applications such as BIM deepening design and collision detection[6-8]. The information transmission between upstream and downstream construction links is not smooth, and an effective assembly construction process has not been formed. In addition, There are various types of electromechanical equipment and accessories, and it is difficult to encode information. The products of various manufacturers of electromechanical equipment are very different, resulting in the design of equipment modules with personalized characteristics, and it is difficult to form a standardized design. The mechanization degree is not high. Traditional manual or semi mechanized construction tools such as chain blocks and lifting platforms are often used for electromechanical installation, and prefabricated tools are lacking, resulting in low construction efficiency. The information management is not perfect. The current project management platform is mostly developed based on civil construction, which is not suitable for the management of electromechanical engineering. Therefore, the research focuses on the main electromechanical systems such as HVAC and plumbing, and deeply integrates BIM secondary development technology, module design technology, factory prefabrication technology, and prefabricated construction technology into the entire construction process. An information management platform is developed to communicate and connect various construction links and related technologies, achieving unique coding, standardized design, efficient assembly, and information management of electromechanical modules, and creating an intelligent construction industry model for electromechanical engineering [9].

2 Key Technology

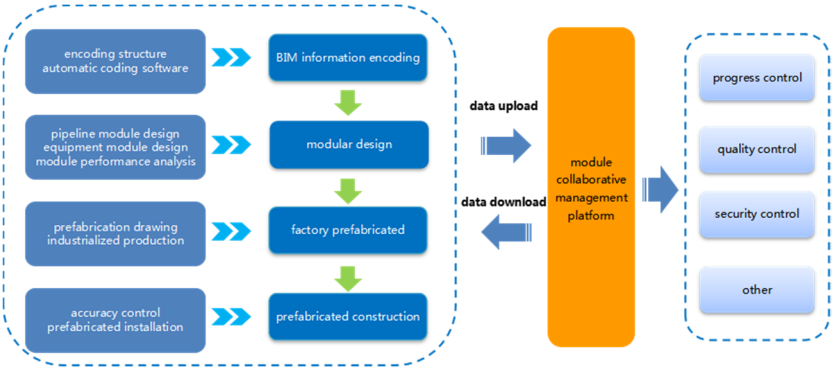


Fig. 1. Technical route of building electromechanical modular construction

From the two aspects of information flow and construction flow, the module collaborative management platform is developed, equipped with automatic production line and prefabricated machinery and tools. A integrated construction model involving modular

design, factory prefabrication, and modular installation has been formed. The technical route is shown in Figure 1.

2.1 Information Encoding of the BIM Model

The types and models of building electromechanical equipment and pipelines are complex, and the information coding is the basis to ensure the accuracy and consistency of the module data in the construction process. Information coding adopts linear layered code, with component positioning as the starting point, and expands from top to bottom until the code reaches to the component sequence number. The encoding structure includes the location information encoding and the attribute information code, as shown in Figure 2.

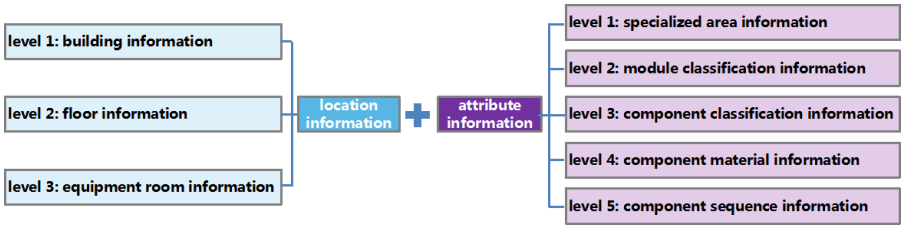


Fig. 2. Encoding structure

According to Revit API interface, the assignment plug-in of electromechanical module information coding is developed. The program encodes the BIM model components, as shown in Figure 3. As a component attribute, encoding realizes shared transmission among different users based on the module collaborative management platform.

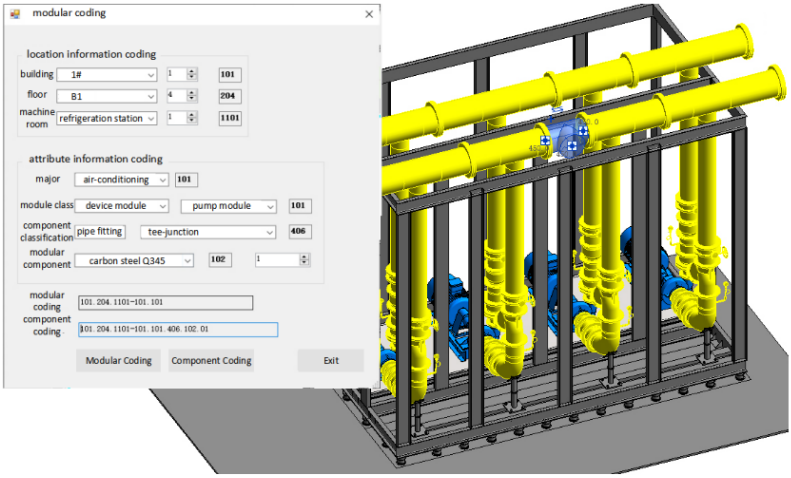


Fig. 3. Automatic encoding of the components

The BIM model information coding technology has established a standardized coding system, achieving uniqueness in the direction of electromechanical modules and significantly improving coding efficiency.

2.2 Modular Design of Electromechanical Engineering

Module design is the basis of modular construction of electromechanical system. According to the structure and functional characteristics of electromechanical system components, it is divided into equipment modules and pipeline modules. The types and models of electromechanical system equipment and pipelines are diverse, and the bottom-up modeling method is low efficiency and prone to error. Therefore, an innovative top-down design approach is adopted.

2.1.1 Pipeline Module Design.

According to existing Revit families, secondary development is carried out to form a pipeline module cutting weld family. The weld family automatically adjusts the width of the weld according to different pipe diameters, wall thicknesses and welding methods. Weld family setting parameters include pipe wall thickness, outer diameter, welding groove type, weld groove length, etc. Add the weld family regularly, add the weld family automatically in the interface, and the total welding amount of the main system and the welding amount of each weld shall be accurately counted, so as to realize the fine management of the weld. Figure 4 shows the completed pipeline module.

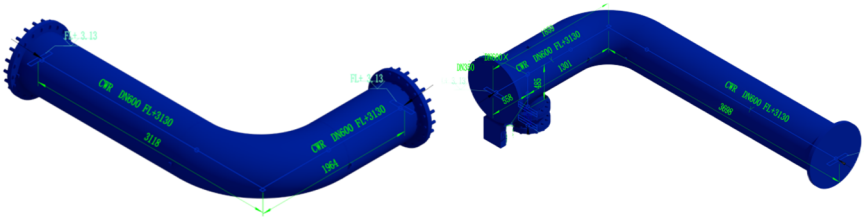


Fig. 4. Typical pipeline module

2.1.2 Equipment Module Design.

The parametric equipment families that meet the requirements of model size accuracy, precise positioning of pipeline interface and adjustable installation position is established. Engineering parameters (pump flow, head, weight, etc.) are added to the equipment families, and the module correlation parameters are reserved, which are embedded in the enterprise BIM family library.

Relying on the enterprise BIM family library, combined with the product customization of equipment manufacturers, the specification parameters of each component of the module are linked to the main control parameters of the module body by directly calling the established equipment product family, completing the overall parameterized linkage design of the module and achieving efficient modular design of the equipment

module. Figure 5 shows the parametric part family, and Figure 6 shows the pump group module.

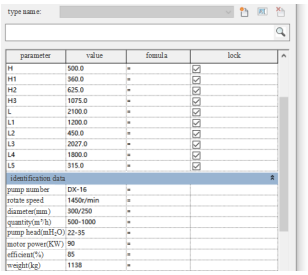


Fig. 5. Parameterized BIM family

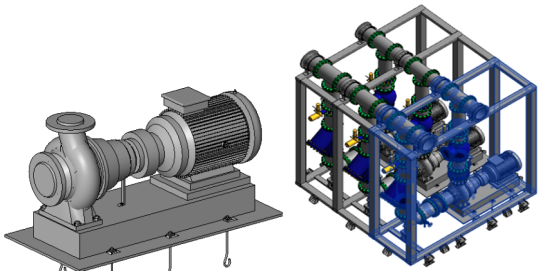
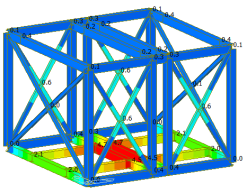


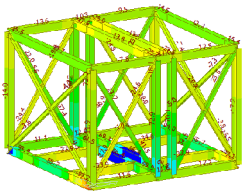
Fig. 6. Pump group module

2.1.3 Performance Analysis of the Module Framework.

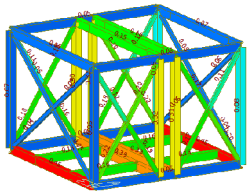
The module frame is the basis to ensure the safety and stability of the electromechanical equipment operation process. Taking the high integrated circulating pump group module as an example, the load is added according to the actual force characteristics of the module frame structure components, and the force performance of the section is analyzed, so as to ensure that it can achieve high quality results in material saving, safety and reliability, convenient installation and other aspects. After calculation, the strength, stiffness and stability of the module meet the design requirements, and the structure is safe and reliable. Figure 7 shows the finite element analysis of the high integrated circulating pump group module.



a displacement contour map (mm)



b distribution diagram of stress (N/mm^2)



c maximum combined stress ratio component

Fig. 7. Finite element analysis of high integrated circulating pump group modules

The modular design technology of electromechanical engineering achieves efficient top-down design of electromechanical modules through the development of digital design software. At the same time, it combines finite element technology to analyze the stability of modules under operating conditions, solving the problems of low efficiency and large consumables in traditional module design methods.

2.3 Factory Prefabrication Technology

Factory prefabrication is the key to restrict the construction progress and quality of electromechanical system assembly. This technology realizes the factory and automatic production of electromechanical modules from the aspects of prefabrication drawing, information integration, automatic production line, etc.

2.3.1 Prefabricated Processing Diagram.

The positive isometric mapping in petrochemical engineering was introduced into the BIM drawing technology in an innovative way, and the drawing expression style conforming to the prefabrication technology was developed to generate the electromechanical prefabrication axonometric mapping meeting the prefabrication precision, clearly reflecting the pipe size and accurately counting the component materials. Through secondary development technology docking Revit software API port, automatic labeling plug-in is developed, which can intelligently identify pipeline system, pipe fitting type, valve parts, define annotations and annotation styles uniformly, and automatically complete pipeline system annotations. Figure 8 shows the prefabricated processing diagram of a certain water pump room module.

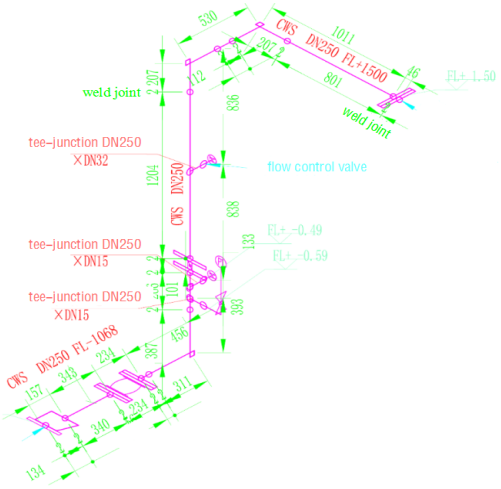


Fig. 8. prefabrication drawing

2.3.2 Industrial Production.

Relying on the enterprise's own assembly processing plant, the automatic processing and prefabrication of the electromechanical system components are realized. The interior is divided into manual material processing area, automatic pipeline production area, assembly area, exhibition area, pipe fittings and pipe placement area, etc., and equipped with 10t driving. The layout is shown in Figure 9.

The automatic production area is equipped with pipe CNC cutting band saw bed, pipe CNC end face groove machine, pipe prefabrication quick group pair, and mobile

pipe welding workstation, which can realize the automation of pipe cutting, slope opening, welding port group pair and welding, as shown in Figure 10.

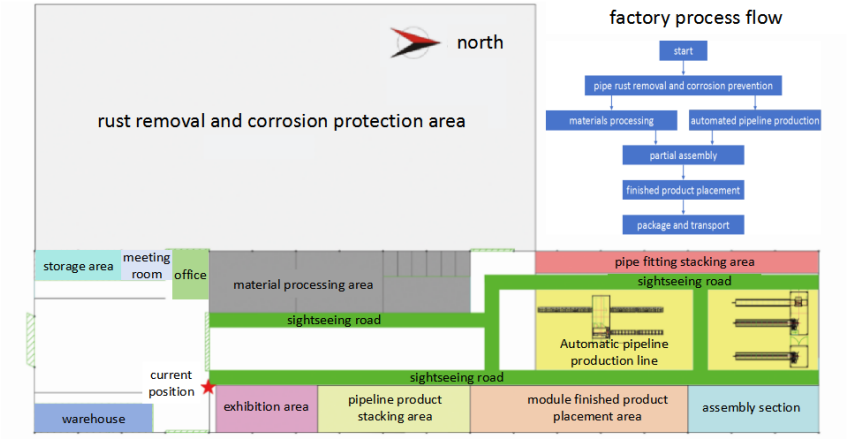


Fig. 9. Factory floor plan layout

a pipe cutting **b** slope opening of pipeline **c** pipeline group pairs **d** automatic welding **e** pipeline module

Fig. 10. Pipeline module prefabrication

An independent assembly area is set up. Prefabricated pipe sections and small modules are used for the overall assembly of large modules. After the module is assembled, paste the QR code logo and move to the display area for display and serve as the storage area before transportation, indicate the used parts and floor information, and prepare the material delivery list according to the actual loading quantity, as shown in Figure 11.

a prefabricated combination risers **b** pump-group module assembly **c** QR code identification

Fig. 11. Module assembly

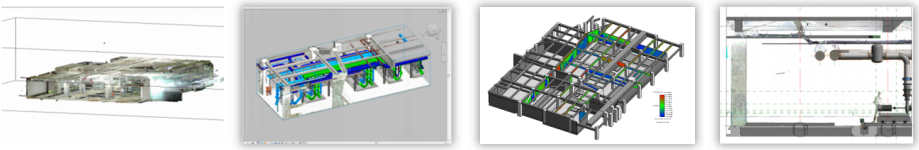
The factory prefabrication technology has innovated the way of producing prefabrication drawings, and established a process oriented prefabrication factory and processing flow, achieving efficient and streamlined operation of mechanical and electrical modules.

2.4 Electromechanical Module Assembly and Installation Technology

The assembly installation technology of electromechanical modules should first accurately locate the electromechanical modules. Then, according to the site layout, building space, module size and structural characteristics, the corresponding module assembly installation scheme is developed, and the assembly installation of the module is carried out by the assembler machine.

2.4.1 3D Laser Scanning Point Cloud Technology.

A 3D laser scanner was used to establish the point cloud of the actual building structure on site. After de-noising, redundant data removal, and axis network matching for the point cloud data, the 3D point cloud model is integrated with the BIM model for chromatic deviation analysis. Problems are identified in areas of large deviation, and the BIM model is adjusted so that the model fits the installation site to a high degree. A realistic and informative virtual building information integration model is formed, which can guide module prefabrication and on-site positioning and layout, as shown in Figure 12.



a 3D point cloud **b** point cloud integration **c** variance analysis **d** model adjustment

Fig. 12. 3D laser scanning

2.4.2 Assembly Installation.

The equipment module is a single module formed by highly integrated components such as frame, equipment, pipes and supports connected to the equipment. For large equipment, it is necessary to establish its pipe set model and rationally use flange segments, which facilitates off-site prefabrication and transportation of pipelines, and realizes on-site installation without welding. After the prefabricated pipeline module is transported to the site, the construction personnel can identify the two-dimensional code and confirm the module information content according to the module label. Piping modules are spliced according to the BIM assembly diagram, and assembly work is carried out according to the construction number and module area. Figure 13 shows the installation process of the electromechanical module.

a module unloading | **b** plumbing module lift | **c** plumbing module fixed | **d** equipment module transfer | **e** equipment and pipeline module connection

Fig. 13. Electromechanical module installation process

The assembly and installation technology of electromechanical modules integrates advanced 3D scanning technology, and develops standardized assembly processes and construction equipment for modules, solving problems such as collision between traditional electromechanical and structural methods, low module assembly efficiency, and significantly improving construction quality.

2.5 Electromechanical Installation and Collaborative Management Platform

A collaborative management platform is developed for the modular construction of electromechanical systems. Based on the three stages of design, prefabrication and construction, the functions of electromechanical component module construction and function customization are highlighted on the basis of the conventional management platform, so as to improve the applicability of the platform in different scenarios, and provide a collaborative environment for the submission and use of unified component models for designers, processing and manufacturing parties and assembly and construction parties. The platform realizes the storage, transmission and sharing of engineering information, as well as progress management, quality and safety management.

2.5.1 Progress Management.

The platform can realize the preparation of schedule, filling of construction progress and inquiry of construction progress. The task can be quickly imported by referencing the engineering structure tree. Task scheduling is implemented based on the start time, end time, duration, and preceding tasks of the task. The construction progress is shown by percentage and different colors. By comparing the deviation between the actual progress and the planned progress, the use plan of personnel, materials and machinery will be adjusted in time for dynamic corrective action. Figure 14 shows the progress management.

2.5.2 Quality and Safety Management.

Quality and safety management is achieved through the issue handling process, which includes issue initiation, pending issue confirmation, confirmed issue, and issue history ledger, as shown in Figure 15. When the on-site personnel find the quality and safety problems, they will use the mobile terminal to send them to the relevant man-

agement personnel and responsible parties in the first time to form a management closed-loop and make the project management more efficient, transparent and informatized.

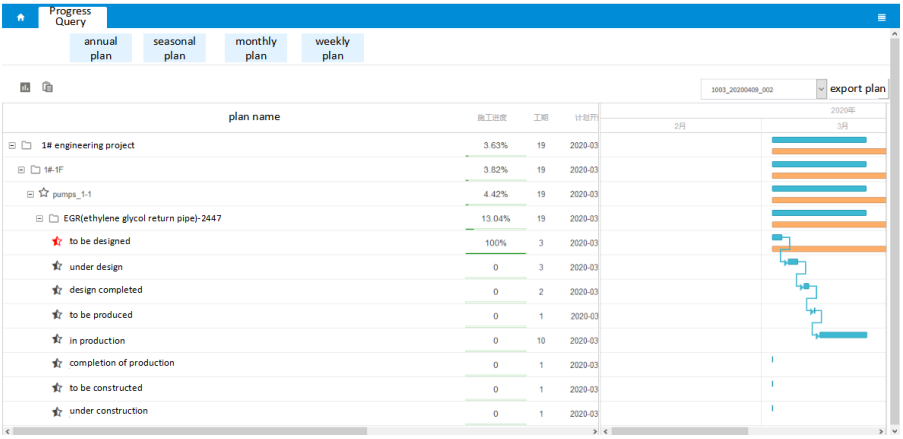


Fig. 14. Schedule management

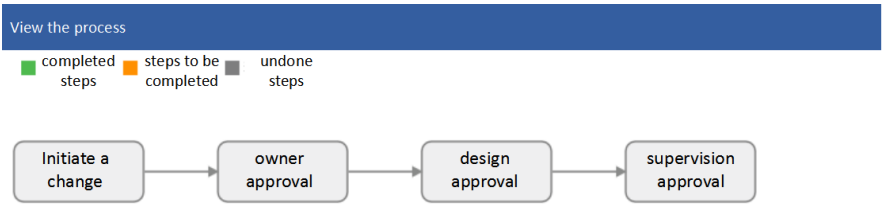


Fig. 15. Quality and safety management process

3 Application Case

Taking Shenzhen World Exhibition & Convention Center as an example, the participating enterprises carried out detailed design and design review through the collaborative management platform, as shown in Figure 16, and completed the detailed design of all 10 computer equipment rooms within two weeks, and all implemented modular construction methods, splitting the electromechanical system into two types: integral modules and component modules, which were prefabricated in the factory and assembled at the construction site. The project began to implement module prefabrication 3 months before the delivery of civil engineering, and the modular installation was completed 1 month after the delivery of civil engineering, which was delivered and commissioned 3 months ahead of the planned construction period, and the effect of cost reduction and efficiency increase was remarkable, as shown in Figure 17.

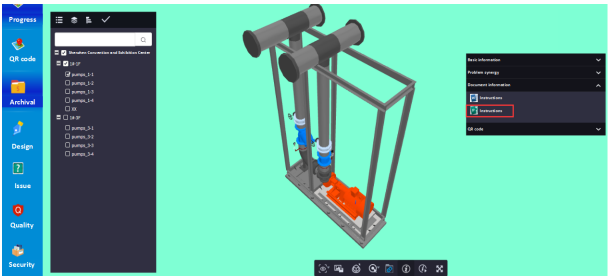


Fig. 16. Platform-based management

Fig. 17. Modular equipment room

4 Conclusion

(1) The technology takes the modular construction process of electromechanical engineering as the baseline, and relies on the module collaborative management platform to communicate and series different construction stages and different participating enterprises, forming a modular standard construction process based on BIM technology, which greatly promotes the progress of the modular construction technology of building electromechanical engineering, and achieves obvious energy saving and environmental protection benefits, reaching international leading level.

(2) Put forward the core coding concept of "location information + attribute information" to achieve a fast and accurate correspondence between the model and the real thing; A top-down module design method is developed to realize the efficient design of electromechanical modules. Innovatively introduce ISO drawing to issue prefabrication drawing, realize automatic annotation of module information, and integrate automatic production line to achieve factory production of modules; Through 3D scanning technology to achieve the accurate positioning of the electromechanical module, the module assembly equipment independently developed by the enterprise successfully solved the problems of positioning and installation efficiency; The BIM collaborative management platform unified the component model submission and use environment of component designers, processing manufacturers and assembly construction parties, and achieved collaborative management of all participants in the process of deepening design, prefabrication and assembly construction.

(3) At present, there are still some limitations in the promotion and application of this technology: BIM model requires high degree of refinement and long modeling time; The prefabrication line has poor adaptability to modules of different specifications and models. Module transportation costs are incurred, and the initial investment costs are high; Module assembly fine-tuning equipment is lacking, and module accurate docking is difficult; The construction conditions are complex, and the transportation and installation of modular components need to overcome space constraints and environmental factors. In the next step, it is necessary to further develop refined BIM family library and collaborative design platform, expand the functional modules of the module production line to achieve flexible production. Reasonable planning of the boundary between on-site prefabrication and factory prefabrication to reduce module

transportation costs; Research and development of heavy module precision positioning equipment to achieve fast and accurate module assembly; Scientific planning of the field module transport path, reduce the difficulties in module transportation and chaotic logistics distribution caused by narrow on-site space scenarios.

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