Basic Study on Data-Centric design information integration system framework development for adapting Nuclear Power Plant construction in Korea

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1. Introduction

This study established the concept of data-centric design, which is the latest design technique, by analyzing the existing literature so that the data-centric design would be applied to the nuclear power plant projects in Korea and analyzed the status of data-centric design application by the advanced companies and the domestic design companies participating in the nuclear power plant projects. By analyzing the function of the 3D CAD commercial system and all design drawings used in the nuclear power plant projects in Korea, a data-centric design integrated system model has been developed. A nuclear power plant construction design information integrated framework, which can manage the design and related information of each Engineering(E), Procurement(P), Construction(C) phase, is suggested for the owner system.

2. Preliminary Review

2.1 Analysis of existing literature

Computer technology using multi-dimensional modeling and other intelligent technologies, along with data, databases, and electronic document sources, are being used extensively. Data centric is an information system managing and storing the information at the object level, independent of the documents depicting the object, able to reconstruct documents based on the data stored with each object in a unified database [1]. Therefore, data-centric design performs design on the level of data (object) unit generated by 3D CAD technique and all information on the design, procurement, manufacturing and construction are integrated and managed based on the data in the center. An important objective of a configuration management programming is to ensure that accurate information consistent with the physical and operational characteristics of the power plant is available in a timely manner for making safe, knowledgeable, and cost effective decisions with confidence [2]. On the research for improving construction planning was studied the feasibility of using Immersive Virtual Environments [3]. 3-D computer models can conveniently be linked to the schedule to provide what is referred to as '4-D'modeling. Deliverables that can be extracted from the CAD drawing model include piping system isometric drawings, general arrangement drawings and materials quantities. These computer models provide visualization for installation planning [4]. The data-centric design is one of the latest technology elements for the shortening of construction period and the saving of cost. During the construction stage, interference exclusion before construction, accurate material quantity estimation and reduction of surplus material are being done by the design review utilized of 3D CAD. Recently, a 3D CAD model is being utilized also during the operation stage [5]. The computer technology forms a computer-based information modeling environment called the virtual power plant. As a result, these New Nuclear Power Plants (NNPPs) will be designed and delivered with a virtual power plant that is comprehensive, detailed, and able to be integrated with plant design, operations, and maintenance processes, as well as databases, document systems, and records systems of organizations that own and operate them [6].

2.2 The current status of data-centric design technique application in overseas

Advanced companies from countries such as Japan, China and Russia establish a 3D design system, perform construction simulation from the design stage and reinforce international competitiveness by reducing rework at field and estimating material cost, labor cost and material quantity. Table 1 is the investigation result on the utilization cases of data-centric design system in the nuclear power plant construction projects by the advanced companies.

Table 1
The status of data-centric design application by the advanced companies

Company (Project)	Description	Ref.
Hitachi (Kashiwazaki -Kariwa)	− Utilize in the field design, construction planning & maintenance management planning − The established CAD model is utilized during the lifecycle stage	[1]
Doshiba (Bellefonte)	− Integrated all design based on 3D CAD by mutual simulation technology − Establish construction plan by linking manpower, material and schedule	[7]
ASE-NIAEP (World Wide)	− Creation of the NPP information model for further issue at all stages of the life cycle − Improvement of layout solutions & construction information model concept − Enabling industrialization of construction and erection work	[8]

As seen in the Table 1, the overseas nuclear power plant advanced companies apply 3D CAD system to all design disciplines including field design, piping, electricity, and instrument design and utilize in the space arrangement among the design disciplines. It has been investigated that it is possible to extract construction drawings, estimate bill of material from a 3D model, integrate the 3D CAD model

and related information By sharing the 3D CAD model and related design information among the suppliers and the construction companies, it is also analyzed it could be data-centric field design, equipment delivery and installation plan for construction.

2.2 Current Status in Korea

The status of data-centric design technique application in Korea is performed by preparing P&ID and SLD (Single Line Diagram) based on the drawings in each field and preparing the material list and procurement specification separately. Figure 1 is a flow chart on the drawing production and design work process, which is being applied on a recent nuclear power plant construction project in Korea, which uses a 3D CAD model.

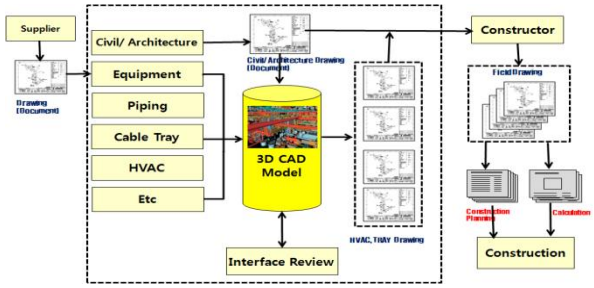

Figure 1: Design process flow by construction stage of a nuclear power plant in Korea

As seen figure 1 is the result of detail analysis on the data-centric design process by construction stage such as the architectural design, civil design and piping design, plant design, equipment design and field design. The ISO drawings produced from the 3D model during the plant architect engineering are also provided to the construction company as document, not as data, and the constructor prepares the construction drawing again for the establishment of construction plan and the material takeoff. It has been analyzed that the design by construction stage in the nuclear power plant projects in Korea is being done by preparing design drawings and transferring the information in the form of document and the sharing and reutilization of the design information among the participating companies is insufficient.

3. Design information integration system framework Development

3.1 Function analysis of latest commercial design system in plant design

The data-centric design techniques are being applied to the nuclear industry due to recent IT rapid advance and the program productivity improvement through the application of data-centric design technique. Table 3 is the analysis result on the major functions and the data-centric design drawings utilized in the overseas nuclear power industry with the commercial software.

Table 2: Analysis result on the major functions of the major software in plant design

Company	Software	Function Description	User
AVEVA	VPE (2D)	− P&ID System Design − Integrated management of related data	AREVA, EDF
	VPD	− Physical design on piping, HVAC and others − Integration of 3D graphic information to a single database − Design interference review among design disciplines − Production of construction drawing	
Bently	Schematic (2D)	− P&ID System design − Data sheet	KEPCO E&C (Some of bentley system)
	3DDesign	− Physical design on piping, HVAC and others − Cable tray catalogues − Support Details	
Smart plant	SPPID	− P&ID System design − SLD, Instrumentation − Integrated management of related data (DB)	ASE-NIAEP
	SPEL		
	SPI		
	SP3D	− Physical design function − Integration of 3D graphic information in all design disciplines to a single database − Design interference review among design disciplines − Production of construction drawing	

3.2 Development of a data-centric design integration system model

Recently Information Technology (IT) rapidly advanced and the program productivity improved after the application of data-centric design technique. Figure 2 are the major functions and the data-centric design drawings of the major software, which supply 3D CAD based plant design.

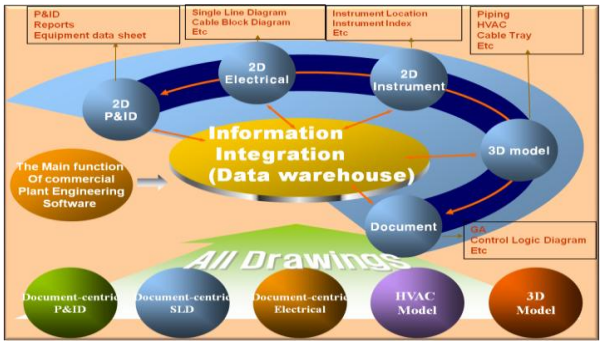

Figure 2: Derivation result of the function requirements

As shown figures 2, the plant architect engineering software used by the advanced companies performs system design including P&ID, electric drawing and instrument drawing. The software performs the design on piping, HVAC, support and equipment as a 3D model and manages the related design information on a single database in integrated way. To apply the new data-centric

design to the nuclear power plant industry in Korea, the detail design shall be done by integrating the 2D design including P&ID, mechanical design and instrument design, the 3D model design on structure, piping and HVAC and the equivalent design model on valves and pumps by referring to the analysis result in Table 5 and the information will be stored in the 'data warehouse'. (Figure 3)

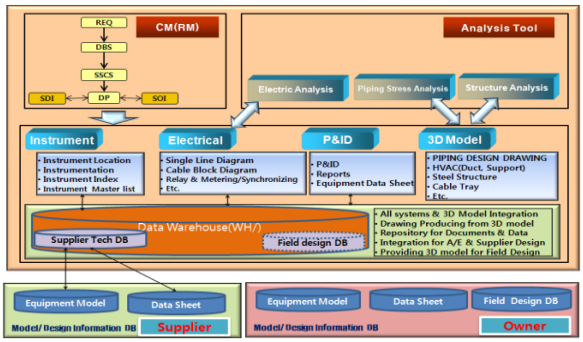

Figure 3: Conceptual diagram on the data-centric design integration system

As shown in the Figure 3, the plan is to establish a foundation so that 3D CAD and related information would be integrated by fully applying data-centric design to the nuclear power plant projects in Korea and produce accurate arrangement drawing, construction drawing, material takeoff and have those shared with the design company and the suppliers. The analysis result on the major functions of data-centric design integration system for effective application to the nuclear power plant projects in Korea is as following. The connectivity and agreement between 2D data and 3D data should be secured. The change control should be performed on the 3D CAD model. The various technical fields including mechanical design, electric design and instrument design should be integrated into a single 3D database so that comprehensive design review would be enabled. The field design should be perfectly built as a 3D CAD database provided by detail design and accurate drawing production and material takeoff should come from the 3D CAD database. The design should exclude field construction interference and construction error while it would have constructability, operability and 4D CAD function so that construction schedule review would be possible.

3.3 Design information integration system framework Development

The owner system in nuclear power plant projects in Korea consists of a nuclear power plant operation system, a procurement system, and a nuclear power plant construction management system, with ERP at the center. There is no continuous flow of design information, that is, the information generated from the job execution results of the design company, manufacturer, and construction company do not reach the owner system unless it would be entered separately. The owner has built and operated the Integrated Nuclear Project Construction Management System (INPCMS), a nuclear power plant construction management system. The construction company has been performing field construction inspection after the construction of the structure, piping, and equipment utilizing the INPCMS. According to construction contract structure in Korea, A Plant A/E contractor is being done exclusively; on the other hand, construction contractor is being done through a bidding competition of big domestic construction companies. Therefore, a design system for the field design of the construction company is required for each project, and there is a limitation in the transfer of all field design–related information from A/E design information to construction companies. To effectively integrate between A/E design deliverables and field design deliverables with the data-centric method, Figure 4 is a data-centric field design system that gives the plant architect engineering drawings and related information to the construction company in a unified database. Like the INPCMS, it will be built as an owner system, and the construction company will perform data-centric field design based on it.

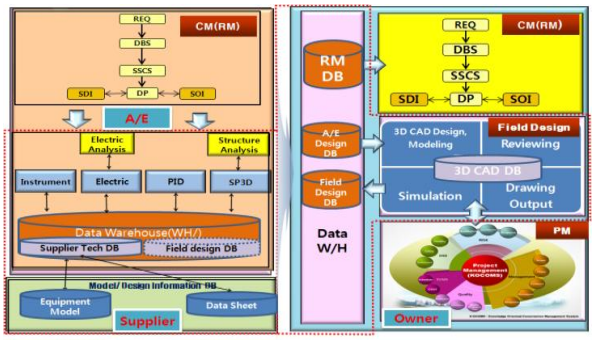

Fig 4. Design information integration system framework

The field design system in the Figure 4 also performs data-centric field design and builds a field design system capable of pre-construction simulation, interference review between works and integration of design model (3D CAD modeling) so that design error would be reduced and field design quality would be enhanced. The design information approved by the field design system and the plant architect engineering information integrated of supplier design information are stored in the data warehouse. This is the design information integration system framework, which provides with consistent and exact information required during the nuclear power plant operation stage.

4. Conclusions

This study established the concept of data-centric design technology, analyzed the functions of the plant architect engineering (A/E) software being globally used in the plant field and the design process status of nuclear power plant projects in Korea. A design information integration system building model, which is capable of data-centric design, in the place of the existing document-centric system design such as P&ID and SLD, has been suggested through the investigation on the data-centric design cases of the advanced companies. The major functions of the suggested model required for the application to the domestic industry were drawn. The supplier design, which has close relation with the data-centric design, the field design process and the field design drawings were analyzed and a nuclear power plant construction design information integration system framework, which can

manage the design products of each EPC stage and the related information in integrated way, has been developed. The suggested framework builds the field design, which was performed in the 3D system of the constructor, as an owner's field design system, which can manage all design drawings generated from the field design and the related information in integrated way. An as-built full model integrated of plant architect engineering, supplier design and field design is built. It is handed over to the operation team at the O&M stage and utilized in the maintenance and repair. As a power plant full model of future construction project has been enabled, an improved design process has been suggested, in which only the design change information during the plant architect engineering (A/E) and the design change information during the field design would be reflected on the reference model. When the framework would be applied to the nuclear power plant projects in Korea, all design drawings and design related information can be integrated; therefore, it is expected that the job productivity of design process and the reliability of the design information would be dramatically enhanced.

Acknowledgment

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