**The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)**
Oct. 11 (Sun) ~ 14 (Wed) 2015 • Paradise Hotel Busan • Busan, Korea
www.iccepm2015.org

# Front End Engineering and Design (FEED) for Project Management of Thermal Power Plant Construction

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***Abstract: Engineering is a value-adding process applying knowledge and skills in the construction industry that includes the planning, feasibility study, project management (PM), front end engineering and design (FEED), detail design, procurement, construction, supervision, and operation. Among these engineering activities, FEED is defined as a comprehensive design practice in the early design phase focused on conceptual design and basic design. It is a particularly influencing area that determines the competitiveness of procurement and construction capability of construction firms (KNIN 2013). Nevertheless, previous studies in FEED have been limited to the design process, deliverable, or particular management technique (e.g. system engineering, collaboration, information etc.). In this context, the purpose of this study is to propose a comprehensive FEED business process structure for project management of thermal power plant construction projects encompassing the entire project life cycle. And an assessment methodology for FEED functions was developed. It is expected that the proposed structure of FEED functions and FEED evaluation methodology will contribute to improvement of competitive capability of engineering, procurement, and construction (EPC) companies.***

***Keywords: Thermal Power Plant Construction, FEED, Project Management, Assessment Methodology***

## I. Introduction

As overseas construction orders by Korean construction companies achieved 66 billion US dollars in 2014, construction orders have continuously increased with focusing on plant business (ICAK 2014). However, considering the total size of overseas construction revenue by Korean companies, it has been controversial over profitability of overseas construction projects at the current point (Son 2013). This controversy over profitability has been caused by EPC contracts with the lowest price and intensive competition among the Korean companies (MOSF 2013; Son 2013). To address this issue, it is urgently needed to secure competitiveness in high value-added plant engineering technology including Project Management (PM) and Front End Engineering & Design (FEED).

Especially, as the major equipment items are determined at the phase of FEED, it not only has a significant influence on the entire project but also plays a decisive role in raising competitiveness in the equipment suppliers and plant package industry (KNIN 2013). That is to say, it is imperative to reinforce the FEED capability in order to create high-added value in overseas plant construction projects and raise competitiveness in winning orders.

Despite the importance of the FEED in overseas plant construction projects, previous studies on FEED have been usually focused on processes or deliverables of FEED at the design phase; especially, studies from the perspective of PM has been carried out only for particular management techniques (e.g. SE, collaboration management, information management, interface management, etc.) with lack of research on FEED from the perspective of PM for the impact on the entire project (See Table I).

For these reasons, this study presents the structure of FEED functions from the perspective of PM specifically for thermal power plant construction projects. Based on a thorough literature review, this study developed the FEED functions with hierarchical structure, and the proposed FEED functions were evaluated by experts for practical validation. In addition, a survey was conducted to assess these FEED functions in order to present current implications as well as future directions for enhanced FEED capability.

## II. Definition & Scope of FEED

As an acronym of "Front End Engineering and Design," FEED is defined as comprehensive design for overall design activities (KNIN 2013) or planning and designing a definitive project at the initial stage of the project (Ki et al. 2013). FEED also refers to activities to minimize changes in design at the stage of carrying out an actual project and optimize construction expenses by establishing a basic plan and concept of design for plant construction (Choi 2009).

The scope of FEED is different depending on whether previous studies include its design concept and basic design. A majority of studies include both conceptual design and basic design, while some authors include only basic design as illustrated in Table I. Choi et al. (2014) defines FEED as a connecting design process, which is implemented after basic design and before detail design.

From the project management (PM) perspective influencing the entire project, the scope of FEED in this study includes 'planning tasks' including feasibility study and organizing a FEED team, as well as 'initial design tasks' such as comprehensive design and design management before detail design (See Fig. 1).

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TABLE Ⅰ
LITERATURE REVIEW IN FEED STUDIES

| | | Lee (1991) | KIMM (1994) | Lee et al. (1995) | Lee et al. (2006) | Choi (2007) | Won et al. (2009) | Hwang et al. (2009) | Chung et al. (2009) | Lee et al. (2009) | Kim et al. (2009) | Choi et al. (2010) | Min (2010) | Hwang et al. (2010) | Min et al. (2012) | Ki et al. (2013) | Kim et al. (2014) | Yun et al. (2013) | Lee (2014) | Choi et al. (2014) | Black & Veatch (1996) | Tensaka (2012) | Devon &Jablkow (2012) | **This Study (2015)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Scope | Conceptual Design | ● | ● | ● | ● | ● | - | ● | - | - | - | ● | - | ● | ● | ● | - | - | ● | - | ● | ● | ● | ● |
| | Basic Design | ● | ● | ● | ● | ● | - | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | - | ● | ● | ● | ● |
| Focus | Deliverable | ● | ● | - | ◎ | ● | ◎ | ◎ | - | - | - | - | ● | ◎ | - | ◎ | - | ◎ | ◎ | ● | ● | ● | - | ● |
| | Design Process | ○ | ● | ● | ◎ | ◎ | ● | ● | ● | ● | ● | - | - | ● | - | ● | - | ◎ | ● | - | ◎ | ● | ● | ● |
| | Development Strategy | ● | - | - | - | - | - | - | - | - | - | ● | - | - | ● | - | - | - | - | - | - | - | - | ◎ |
| | Management | ○ | ○ | - | Information | - | Knowledge | ○ | - | - | - | ○ | ○ | - | ○ | SE* | Interface | Collaboration | SE* | - | ○ | ● | ◎ | ● |

Legend:● Focused ◎ Covered ○ Mentioned
* SE: System Engineering

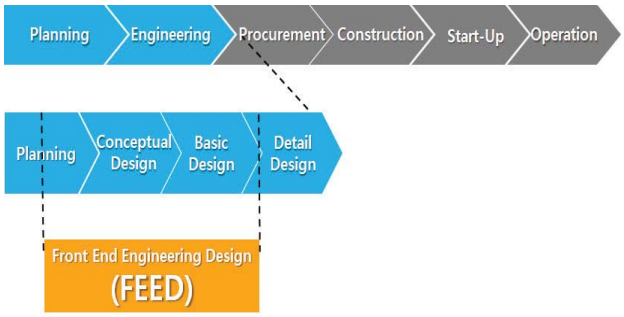


FIG.1 BUSINESS SCOPE OF FEED (WWW.SIEMENS.COM)

## III. FEED FUNCTIONS FOR PROJECT MANAGEMENT

### *A. Structure of FEED Functions*

First, the definitions of FEED which are presented in previous studies were analyzed to draw the structure of FEED functions from the perspective of PM.

However, studies presenting FEED functions are currently insufficient; to supplement this weakness, FEED functions which are suggested by international companies were surveyed and analyzed as shown in Table II.

Result of the literature review shows that most studies have a different level of details (LOD) for FEED functions but commonly present in a three-level hierarchical structure. This study supplemented and reorganized FEED functions which are presented by previous studies and advanced international companies, mainly based on Tensaka (2012) that introduces real-world projects conducted by FEED business. As a result, the study identified the FEED functions from the perspective of PM with a three-level hierarchical structure. Further, these functions were revised and supplemented with verification by three industry experts in the FEED area.

The first level of the structure in this study is defined as "FEED phase" with six phases. The second level is called "FEED functions for each phase," which is equivalent to the first level, with 33 items. The third level refers to "FEED detailed functions for PM" with 155 items in total.

TABLE Ⅱ
LITERATURE REVIEW IN FEED STUDIES

| Study | Classification Criteria | FEED Business | | |
|---|---|---|---|---|
| | | Lev_01 | Lev_02 | Lev_03 |
| Lee (1991) | Deliverables | 2 | 10 | 43 |
| Choi (2009) | Deliverables | 6 | 36 | 27 |
| Lee (2013) | Deliverables | 3 | 23 | 69 |
| EMERSON (2005) | Business Process | 5 (Phase) | 15 | 12 |
| SIEMENS (2006) | Deliverables | 9 | - | - |
| CARMAGEN (2010) | Deliverables | 8 | 30 | - |
| Tensaka (2012) | Business Process | 9 (Phase) | 44 | 169 |
| **This Study (2015)** | **Business Process** | **6 (Phase)** | **33 (Function)** | **155 (Detail Function)** |

TABLE Ⅲ
A STRUCTURE FEED FUNCTIONS FOR PROJECT MANAGEMENT

| Level_01 FEED Phase (6) | Level_02 FEED Functions (33) | Level_03 FEED Detail Functions (155) |
|---|---|---|
| FEED Planning | Objective Setting | Identifying Project Objectives, Identifying FEED Objectives, FEED Team Organization |
| | Feasibility Study | LCC, Site Detail Analysis, Power Process Technical Development |
| | FEED Execution Plan | FEED Schedule Plan, Resource Plan, Project Charter |
| Preliminary Study | Project Requirements | Owner's Requirement, Licensor Information, Reference Plant |
| | BEDD | Climatic Data, Utility Information, Equipment Code & Standard, Environmental Regulations, Local Code, Safety Regulation, Operating Flexibility Requirement, Specific Instructions |
| Conceptual Design | Design Basis | Owner's Input, Project Description, Duty of Unit, Feeds Specification, Products Specification, Battery Limit Conditions, Utility Conditions and Site Information, Operating Conditions |
| | Process Analysis | Process Simulation, Heat and Material Balance, Preliminary Equipment List, Process Datasheet |
| | Project Layout | Site Plot Plan, Project Schedule Plan, Preliminary Estimation |
| Basic Design & Engineering | PFD | BFD (Block Flow Diagram), System PFD, Utility PFD |
| | Process Equipment Datasheet | Material Selection, Pressure, Temperature, Equipment Size Criteria |
| | Equipment Specification | Pressure Vessels, Rotating Equipment (Pumps, Blowers, Compressors), Heat Exchangers, Packaged Equipment, Electrical Equipment and Instruments |
| | P&ID | Major Equipment, System, Utility, Process System, Single-line Diagram |
| | Equipment Quotation | Identification of High-value Equipment and System, Vendor Bid List, Purchase Order, Support Equipment Bidding, Formal Bid Tabulations, Selection Vendor List |
| | Plot Plan | Constructability, Operability, Maintainability |
| | 3D Modeling | Interface, Interference, Material Specification, Structural Steel Data, Electrical System Connectivity, Plant Overall Process Flow Criteria, Construction Sequencing, Operator Accessibility, Safety Feature, Configuration Document, Subsequent Design Change Document |
| | Bulk Material Quantification | 3D Model - Foundation, Structural Steel, Piping, Plan Drawing - Electrical, Control System |
| | Bulk Material Quotation | In-house/Recent Project Purchase Order Value, Informal Quote from Preferred Supplier, Formal Competitive Bidding |
| | Summary | Flow Stream, Utility System, Environmental, Pipeline Flow |
| | Design Review | PFD Review, HAZID, P&ID Review, HAZOP |
| EPC Execution Planning | Major Consideration | Contract Terms, Labor Availability, Site Logistics, Technical Complexity, Major Equipment and Material Sources, Extent of Field Fabrication |
| | Execution Method and Schedule | Integrated EPCS Schedule |
| | Engineering and Support Services | Design Deliverables Schedule, Specialty Third Party Subcontracting, Multi-Office Execution, Procurement Plans, Construction Support |
| | Procurement | Material and Equipment Providing Method, Portion of Subcontract |
| | Construction | Labor Survey, Procurement Plan, Site Mobilization Timing, Craft Level, Work Sequences, Subcontract Award Dates, Quoted Work Duration |
| | Start-Up | Start-up Planning, Single Inspection Plan, Comprehensive Inspection Plan |
| Estimation | Project Code of Accounts | Civil, Architectural, Mechanical, Piping, Electrical, Instrumentation/Control, Temporary Facilities, Construction Management, Construction Equipment, Home Office, Freight, Commissioning and Start-up, Miscellaneous Costs |
| | Purchased Costs | Owner Purchased Costs |
| | Construction Costs | Contractor Furnished Material Costs, Construction Labor, Construction Management, Construction Equipment, Construction Insurance, Performance Bonds, Permit Costs |
| | PM Costs for Home Office | Project Management, Procurement, Contract Management, Project Control, Information Technology Support, Project Accounting, Quality Assurance/Control, Financing/Commitment/Letter of Credit Fees |
| | CM Costs for Field Office | Water Interconnection, Construction Management, Commissioning and Start-up, Property Tax during Construction |
| | Miscellaneous Costs | Freight and Logistics, Import Duties/Fees, Land, Owners' Contingency, Development Cost Reimbursement, Initial Fuel Inventory, Builder's/Marine Cargo/Liability Insurances |
| | Contingency | Account for Potential Risk Items |
| | Capital Costs | EPC Cost, Owners' Costs, Financing Fee, Interest during Construction, Escalation for Construction Duration |

### *B. FEED Functions for PM*

Table 3 lists the structure of FEED functions from the PM perspective which is presented in this study. Based on six phases at Level_01, FEED functions (Level_02) and detailed functions (Level_03) were identified.

*1) FEED Planning Phase*: It is the starting and basic point for conducting FEED from the perspective of PM by making a plan. FEED functions at this phase include Objective Setting, Feasibility Study, and FEED Execution Plan.

2*) Preliminary Study Phase*: It is the phase to gather various common basic conditions using for design by collecting materials to review information and major requirements from an owner and licenser. FEED functions at this phase include Project Requirements and BEDD.

3*) Conceptual Design Phase*: It is the phase to establish standards for design and analyze the plant process based on information and basic conditions to conduct the project which is established at the FEED planning and preliminary study phase. FEED functions at this phase include Design Basis, Process Analysis, and Project Layout.

4*) Basic Design & Engineering Phase*: It is the phase to decide a list and specifications for major equipment and design result in major performances in FEED business. FEED functions at this phase include PFD, Process Equipment Datasheet, Equipment Specification, P&ID, Equipment Quotation, Plot Plan, 3D Modeling, Bulk Material Quantification, Bulk Material Quotation, Summary, and Design Review.

5*) EPC Execution Planning Phase*: It is the phase to establish a plan for conducting the project by considering the most efficient and cost-effective methods on the basis of major FEED performances which are drawn in the basic design & engineering phase. FEED functions at this phase include Major Consideration, Execution Method and Schedule, and establishment of each detailed EPCS (Engineering and Support Services, Procurement, Construction, and start-up) plan.

6*) Estimation Phase*: It is the phase to compile the budget for business expenses from the perspective of an owner before conducting EPC project based on major FEED performances which are drawn at the compile of basic design and a business plan established at the EPC execution planning phase. FEED functions at this phase include Project Code of Accounts, Purchased Costs, Construction Costs, PM Costs for Home Office, CM Costs for Field Office, Miscellaneous Costs, Contingency, and Capital Costs.

### *C. Assessment of FEED Functions*

For the above-mentioned FEED functions, major 19 functions were selected as 'FEED evaluation measures' among 33 items of FEED functions at Level_02 by an extensive review and expert interviews. An assessment for each measure was then conducted. The interview as a structured survey was conducted with six PM experts with minimum 20 years of experiences in conducting FEED businesses for thermal power plants construction projects. For each assessment measure, "Business Importance" and "Business Capability" were evaluated. Five-point scale was used, and the respondents' scores were normalized and analyzed by 100-point scale.

The result of assessment indicates that the Korean construction industry have high 'capability' in design-focused functions; however, in terms of 'importance', the functions from the PM perspective considering planning, feasibility, and costs were more important than others. Despite the importance, business capability of these functions was relatively insufficient for Korean companies as shown in Fig. 2. This result shows that the FEED business for thermal power plants construction projects need reinforcing the business capability from the perspective of PM such as planning, costs, schedule, and review of conditions for an owner and feasibility.

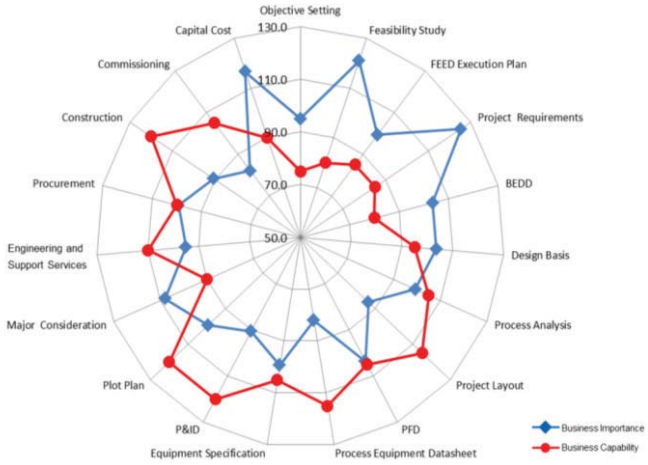


FIG.2 COMPARATIVE ANALYSIS OF FEED ASSESSMENT

As shown in the Figure 2, the proposed methodology can be effectively used to evaluate the current status and future direction of FEED management for an organization. It is expected that the structure of FEED functions from the perspective of PM, which is proposed in this study, will significantly contribute to reinforcing capability and securing competitiveness of FEED business in the overseas thermal power plant construction projects.

## IV. CONCLUSION

This study developed the structure of FEED functions from the perspective of PM for thermal power plants

construction projects in order to enhance competiveness of overseas power plant construction. The FEED functions developed in this study have three-level hierarchal structure: the Level_01 is composed of six phases of FEED, while the Level_02 is defined as FEED functions for each phase with 33 items. The Level_03 is composed of 155 items in total as FEED detailed functions.

Further, based on the assessment of major 19 functions among functions at Level_02, it has been identified that functions based on design performances have high capability, while management-focused functions currently have low capability despite of their importance.

Under these circumstances, the FEED functions from the perspective of PM are expected to become one of important guidelines for Korean EPC companies to conduct FEED businesses more efficiently in overseas power plant construction projects in the future.

## ACKNOWLEDGEMENTS

This study was supported by "Basic Science Research Program" through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT, and Future Planning (MSIP) under Grant no. 2014R1A2A2A01006984.

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