Introduction

An EPC project is a well-known project management term used internationally. It refers to performing a complete project on a lump sump turnkey basis which encompasses the engineering, procurement and construction of the whole project. The FEED (front end engineering design) forms the basis of detailed design of the complete project, which in turn generates the basic data for the procurement and civil, mechanical, electrical and instrumentation (CME&I) works of an EPC project. The project objective is to ensure safe, timely, and successful completion of the EPC project within allocated budget.

EPC and EPCM Contracts

EPC stands for Engineering, Procurement and Construction. It is a common form of contracting arrangement within the construction industry. Under an EPC contract, the contractor will design the installation, procure the necessary materials and construct it, either through own labour or by subcontracting part of the work. The contractor carries the project risk for schedule as well as budget in return for a fixed price, called lumpsum or LSTK depending on the agreed scope of work.

When scope is restricted to engineering and procurement only, this is referred to as an EP or E+P contract. This is often done in situations where the construction risk is massive for the contractor or when the Owner prefers to do construction himself.

EPCM refers to Engineering, Procurement, Construction Management. It is a common form of contracting arrangement within the construction industry. In an EPCM arrangement, the contractor is not in fact the constructor. Rather the EPCM designs, procures and manages the construction process as an agent of the project Owner. While the C stands for construction, this is in the context of CM, Construction Management. Unlike an EPC contract, an EPCM contract is essentially a contract for professional services, based on a schedule of rates.

EPC and EPCM contracts are quite different in terms of risks and allocations. The advantage from the Owners' point of view of an EPC contract is that the contractor takes full responsibility in respect of the following:

- cost of completion if it is a lump sum contract (subject to limited adjustments)
- the time for completion (subject to extensions of time)
- the quality of the design and work and achievement of performance guarantees (subject to any exclusion)

The potential for multiple disputes is avoided in EPC. However, the major disadvantage for the Owner of the EPC contract, when compared to the EPCM contract, is that the detailed design is the contractor's prerogative. Accordingly, in an EPC contract, great care needs to be taken that the Owner specifies and defines the design parameters and deliverables, including consumption of utilities and emissions.

Substation EPC Project

In EPC contract, the Contractor is responsible for all design, procurement and construction services needed to complete a substation. These services may be performed solely by the contractor or sub-contracted to others. The Client, in turn, typically has a number of responsibilities that include providing final substation circuit diagrams, procurement specifications, design criteria, site selection, site plans and obtaining regulatory permits.

A Substation EPC project life cycle includes:

- Pre-Qualification
- Submitting the Proposal to the Client
- Negotiation with vendors, subcontractors and Client
- Design and Procurement of major equipment
- Construction
- Testing and Commissioning
- Operation and transferring the substation and warranty of equipment to the Client

Successful substation EPC project delivery is dependent on assembling the right project team. Substation EPC project teams are formed before pursuing an EPC project and tailored to satisfy the Client's needs and specifications. Large Substation EPC project design teams may consist of: a project manager and a project coordinator; an engineering manager, a lead electrical engineer and one to three electrical engineers; a lead civil engineer and one to three civil engineers; a drafting manager, one to three drafters; permitting and land acquisition; a purchaser; a construction manager, a contractor, and subcontractors.

In order to facilitate the process of understanding the project's scope, prior to the start of the Design Phase, the contractor must hold a partnering session attended by the in-house Design-Build team as well as the Client's team. The partnering session provides an overview of the design-build schedule, quality control plan, permit requirements and coordination of the work between all entities.

Some of the activities of a substation EPC project may not be started before other tasks or portion of tasks or activities have been completed. For example, foundations for the steel structures must be in long before erecting the steel structures can start. Site grading and excavation must proceed before installing the steel structure foundations.

Role of Project Design Team

The Client's responsibilities include identify project goals, decide a project delivery system, determine whether Client needs assistance of a consultant, select a representative and determine any limitations on the representative's authority, decide upon a procurement process for EPC, determine the appropriate payment methodology for EPC contract, allocate project risk, obtain project financing, furnish site information, identify deliverables, review and approve design submissions of EPC, inspect construction for compliance with contract, develop efficient change order process, and obtain appropriate project insurance. The substation EPC project design team's responsibilities include deliverables according to the contract between Client and the Contractor. The Electrical engineering group develops the electrical drawings and the Civil engineering group develops the civil drawings for Client's review. The electrical and civil drawings will be issued for construction after Client's approval. Substation EPC project design team also reviews and approves vendor drawings.

Project coordinator keeps track of the electrical and civil deliverables and construction activities. Design criteria is very important for a substation EPC project because substation equipment, materials, and construction cost will be established using the defined design criteria.

If design criteria changes in the middle of the EPC project, engineering and construction reworking cost can be expensive for both the Client and the Contractor. Quality Assurance and Quality Control Program must be involved throughout the length of the project to ensure that project objectives are met. Design manual, detailed civil and electrical engineering design for the substation EPC project will be provided to Client by the Contractor.

Project Design

Substation will be designed in accordance with applicable Client's standards, industry standards and codes, and central, state or local requirements. Packages such as MicroStation or AutoCAD are employed for detailing and drafting applications. The project design manual addresses the specific parameters of the design including applicable standards, codes, and interpretations of codes and standards that may affect the design. The project design manual also addresses the scope of the project and any specialized or unique design techniques used in the development of the design documents.

Client's specifications provide a comprehensive approach to the procurement process, and pre-qualify suppliers. Substation equipment and materials bid documents include bid forms, general requirements, design condition, major equipments, steel structures, equipment and materials, control building, and relay panels. Substation construction includes construction management, site work including grading and erosion control, installation of fence, major equipments, foundations, grounding, conduit, raceway, control building, relay panels, and steel structures erection and equipment testing.

Avoidance of any occupational related deaths or injuries must be accorded high priority. Subcontractors must be made aware from the onset that safety will play a significant role in the success of the project.

Critical Path Method (CPM) Schedule

CPM Schedule is a network scheduling technique where large elements of a project are subdivided based on a hierarchical system (work breakdown structure) into single work steps (activities) and sequenced based on interrelationships such that time usage can be calculated to determine the earliest date work can be accomplished and the latest date work needs to be completed. The critical path is the longest activity path from the start to finish of the project.

An activity, which is not on the critical path, will have float. Float is the amount of time an activity can be delayed without it becoming a critical path activity. Any activity on the critical path that experiences a delay will consequently delay the project milestone or completion date or require corrective action.

CPM Schedule forces the scheduler, construction supervisor, and the project manager to think through the entire project in detail to avoid inefficient and poor sequencing of the project, and helps the project manager to define and plan the work in detail from start to finish. Sequences can be changed to overcome or reduce any impact. CPM Schedules support efficient communication between field and office forces. It can assist in a smooth transition for execution of the plan if management staff changes are made during

the project. It makes job coordination easier among material suppliers, contractors, subcontractors, client, and designers.

Client's Responsibility in Substation EPC Project

The Client's primary function is to create the project and pay for it. The Client also has the corresponding duty to manage how the project will be developed and selecting a project delivery system. A 15-point checklist for Client's responsibilities, as follows:

- Identify project goals.
- Decide upon a project delivery system, which will give the Client best chance to achieve project goals.
- Determine whether Client needs assistance of a consultant.
- Select a representative and determine any limitations on the representative's authority.
- Decide upon a procurement process for EPC.
- Determine the appropriate payment methodology (e.g., cost plus, lump sum) for EPC contract.
- Identify and allocate project risk.
- Obtain project financing.
- Furnish site information.
- Secure agreements with adjacent property Clients.
- Identify Client-furnished deliverables (e.g., permits, furnishings) and develop process for timely obtaining such deliverables.
- Review design submissions of EPC.
- Inspect construction for compliance with contract.
- Develop efficient change order process.
- Obtain appropriate project insurance.

The Client of an EPC project typically is responsible for obtaining many permits and Approvals. It is important for the Client to have a clear understanding of its permit obligations and the Client must have a plan in place for obtaining such permits and approvals. Client's inability to obtain the permits and approvals can result in major delays in the project.

Substation Design Criteria

Design criteria is very important for a substation EPC project because substation equipment, materials, and construction cost will be established using the defined design criteria. Project design conditions are information that are applicable to all structure, equipment and material designs. Seismic zone, altitude, annual precipitation, design loading district, wind velocity, and ice accumulation information is useful in substation design and are to be provided to the equipment and material suppliers for use in their designs.

Weather data influences the design for the area of the substation. Temperature, isokeraunic level, wind speeds, and ice play a big role designing substations. Substation electrical system information is required to design optimally. The electrical system ratings include nominal system voltage, maximum system voltage, station BIL, available fault current, continuous current, short circuit withstand current, and system frequency. The substation structure design load cases are necessary to know before the substation structure calculations start. The substation structure design load cases including weight of equipment, structure, light, medium, and heavy wind, short circuit and ice loadings determine the size of the structures that will be required for the substation.

The rigid bus design helps to accommodate alternate feeds through adjacent breakers in the event of required maintenance or line fault. Electrical clearances for the bus must be maintained to protect people and equipment moving underneath the substation. Phase-to-ground and phase-to-phase clearances should be coordinated to ensure that possible flashovers occur from phase-to-ground rather than from phase-to phase.

Major substation electrical equipment is custom designed, has longer delivery time, and is expensive. Substation grounding protects personnel from touch and step potential. The touch and step voltages produced in a fault condition have to be at safe values. The substation grounding system consists of driven ground rods, buried interconnecting grounding cables or grid, equipment ground mats, connecting cables from grid to metallic parts of structures and equipment, connections to grounded system neutrals, and the ground surface insulating covering material.

Substation electrical equipment can be subject to abnormal conditions as a result of direct lightning strokes. Shielding design analyzes and recommends procedures for direct stroke protection for the substations and substation equipment.

Raceway in the form of conduit, tray, and trench, are used in the substations to provide protection

and segregation of cables. Raceway sizing is an important parameter in substation design notably for a large installation. Protective relays detect defective lines or apparatus and initiate the operation of appropriate circuit interrupting devices in order to isolate the defective lines or equipment. Relays also detect abnormal or undesirable operating conditions, other than those caused by defective equipment and either operate an alarm or initiate operation of circuit interrupting devices.

The high-speed operation of these relays minimizes damage to the electrical system and helps to maintain service continuity to the rest of the electrical system. The type of relay or relay system selected by the substation engineer for an application is of primary importance. The electric system inputs that will be available to the relay and the speed with which the relay must operate to maintain electric system stability must be known.

Site work design of substation yard should be such as to provide an easily accessible, dry, maintenance free area for the installation and operation of electrical substation equipment and structures. A variety of structure types are used in electrical substations and these structures have a wide range of ground line reactions. Typical substation foundation types can be slabs on grade, spread footings, drilled shafts and piling with and without pile caps. Foundations should be designed such that they do not exceed deflection criteria of the structure.

Substation structures are designed to reliably support electrical equipment and maintain clearances. Since excessive structure movement can cause electrical equipment to experience mechanical damage, operational difficulties and electrical faults, structures are designed to meet strength and deflection criteria under a variety of loading conditions.

The control building provides a weatherproof and environmentally controlled enclosure for substation equipment including relays, meters, controls, batteries and communications equipment. Additional space should be provided for workshops, equipment testing and repair and storage. Control building layout includes controls, relay panels, DC equipment, AC equipment, cable tray and lighting.

Problems and Practices in EPC Project Management

EPC projects face many challenges to stay in the competitive world despite the efforts made towards compressing activities by phase overlapping, in order

to reduce time scale and to obtain better EPC projects. These project challenges lead to cost overrun and schedule delay.

Studies reveal that major factors contributing to schedule delay and cost overrun are mostly related to material and equipment such as material shortage, procurement delay or late delivery on site. Besides, delay in placing purchase order, design changes, lack of EPC contractor's experience, late approvals, vendor information coming in late and further most due to the lack of coordination between Client, contractor and suppliers regarding exchange of information are other factors contributing cost overrun and schedule delay.

Poor planning and controlling, lack of top management commitment, unrealistic project scheduling and poor coordination and communication are some more project management practices observed. However, subcontractor management and control mechanism, lesson learnt practice, involvement of construction and operational personnel during conceptual phase are success project management practice found.

Furthermore, interface management and control, integrated team management, real time reaction, dispute management, risk management, stakeholder management, continuous and dynamic detail planning and monitoring during execution and being proactive to issues, carrots and sticks approach (incentive criteria), clear roles and responsibilities, etc are also the big concerns in terms of project management practice regarding controlling cost overrun and schedule delay.

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