Review: Benefits of using a Design-Build Methodology for Geothermal Power Station Steamfield Projects

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ABSTRACT

Design-Build (DB) is a project delivery model that has been successfully implemented in a number of geothermal energy projects in New Zealand. This paper explores the benefits of assigning the design and construction phases to a single entity (Contractor) in geothermal power station steamfield projects, while also describing best practices and lessons learnt. Project parameters such as cost, risk assignment and delivery times are analysed for multiple projects. Furthermore, contractual agreement recommendations for design-build projects between the Contractor and project owner are presented, including technical specifications, performance requirements and commercial conditions.

1. INTRODUCTION

1.1 Project Delivery Method

A project delivery methodology is a system used to plan, execute and complete a project within an established timeframe, cost and appropriate quality assurance system. In the construction industry, three main types of project delivery system are commonly used (Overcash, 2005):

- Design-Bid-Build (DBB)
- Construction Management (CM)
- Design-Build (DB)

The DBB is the traditional approach for construction. This system involves two major parties in the project life: the Designer and the Builder. This methodology has a linear sequence of work since in theory it requires that the design documents be completed in order to submit them for bid among the construction firms to secure the lowest cost. Several geothermal steamfield projects in New Zealand have been carried out under this system.

The CM methodology assigns a manager responsible for the construction phase of the project. The construction manager normally engages a design consultant earlier to start planning the construction (Sullivan et al. 2017). This system is not normally followed in geothermal steamfield projects in New Zealand.

The DB involves an entity designated by the project owner to execute and to complete the project from the design phase to the construction phase, i.e. a Contractor runs the project on behalf of the project owner from start to finish. In New Zealand, this system has been widely used in many steamfield projects aiming to overcome deficiencies from having separate contracts for design and build parties as DBB.

Note: Engineer-Procure-Construct (EPC) is a term commonly used in the construction industry. EPC is essentially the same as DB.

1.2 Design-Build Characteristics

The Design-Build Institute of America (DBIA) defines the following main characteristics to DB methodology (DBIA, 2014):

- Integrated service of design and build for a project delivered by a sole entity.
- Single point of contact for the project owner throughout the execution of the project, therefore one contract for design and build phases.
- DB entity selection starts by issuing a request for qualifications to firms, focusing the selection in experience and technical approach.
- Construction input occurs during the design process; hence it is possible to overlap the construction phase with the design phase.
- Project owner requires a defined scope of works in order to maintain a high level of certainty of the expected works vs. costs.

2. DESCRIPTION OF GEOTHERMAL STEAMFIELD PROJECTS IN NEW ZEALAND

2.1 Geothermal Steamfield

A geothermal steamfield, or steam gathering system (SGS), is a fuel supply system consisting of piping and equipment between production/reinjection wells and the geothermal plant that utilises the extracted fluid. This equipment not only involves conveyance of steam/brine but may also include special purpose systems such as antiscalant systems to manage scale build-up or reinjection pump stations.

The boundaries between the geothermal plant and the steamfield equipment are normally defined. The division between the plant and the steamfield is typical due to the different expertise required between the two systems.

2.2 DB Projects in the Geothermal Steamfield Sector

A variety of steamfield geothermal energy projects in New Zealand have been completed under the DB methodology A few examples are:

- Steamfield equipment for the Te Ahi O Maui power station with 25 MW of installed capacity in Kawerau (MB Century, 2018).
- Steamfield equipment for the MRP Kawerau Geothermal Project 90MW power station (Foong et al., 2010).

- Production and reinjection pipelines for the Nga Awa Purua (NAP) power station with 140 MW of installed capacity at Rotokawa (MB Century, 2018).

- Steam separation system for NAP power station (Horie, 2009).

- Steamfield piping at Ngawha 25MW power station (Koorey, 2008).

- Clean steam plant for direct use to supply heat to the Miraka milk factory in Mokai (Taylor, 2011).

- Steamfield equipment for Rotokawa 25MW power station (DB subcontract to station contractor) (MB Century, 2018)

3. ANALYSIS OF DB STEAMFIELD PROJECTS IN NEW ZEALAND

3.1 Steamfield Projects Characteristics

Nine steamfield projects were chosen from MB Century's database to outline project benefits when delivered under a DB methodology. Project aspects such as size, cost, duration, risk, design complexity and scope of works vary among the selected examples. Also, the analysed projects include some or all of the design-build of the following:

- Steamfield equipment such as separators, silencer and steam vents.

- Cross-country large and small bore piping for single and two-phase fluids.

- Instrumentation and control systems.

- Civil works.

- Rotary equipment installation.

Analysis of scope of works and timeline for the present study was based on project contractual terms particular to each project.

3.2 Benefits of DB Methodology in Steamfield Projects

Umanzor et al. (2010) describe a commonly used piping design process among geothermal developers, which also applies to steamfield design. This process starts by defining the design criteria, then the process design, followed by the detailed design, and finally with construction and testing.

The aforementioned project process is relevant to a DBB methodology. The main difference in a DB project is that the design and construction phases are able to overlap since one contractor is in charge of both project stages.

Figure 1 shows a comparison between a generic steamfield project delivered under DB methodology (blue) and DBB methodology (orange). Normally, the geothermal developer is in charge of the design criteria and process design, defining aspects such as pipe sizing, piping layout considerations, isolation methodology, and applicable design codes (Umanzor et al. 2010). After defining the project criteria, the DB and DBB methodologies divert in the subsequent steps. At this point, the steamfield project benefits from a DB contractual scheme as follows:

Delivery Time

The first benefit shown in this study of DB steamfield projects is the superiority in speed of delivery. The DB projects were completed in a timely manner or even ahead of schedule. A DB steamfield project methodology starts by the project owner (or principal) requesting quotations to different contractors based on project criteria. During this process of the project under the DB system, a conceptual design and preliminary Bill of Materials (BoM) is created by each of the tendering contractors. The level of detail on this preliminary plan to execute the project from start to finish is in reality the start of the design and construction phases. Compared to a steamfield project under the DBB methodology, the construction phase cannot start until there is a final detailed design approved by the owner and contractor engaged.

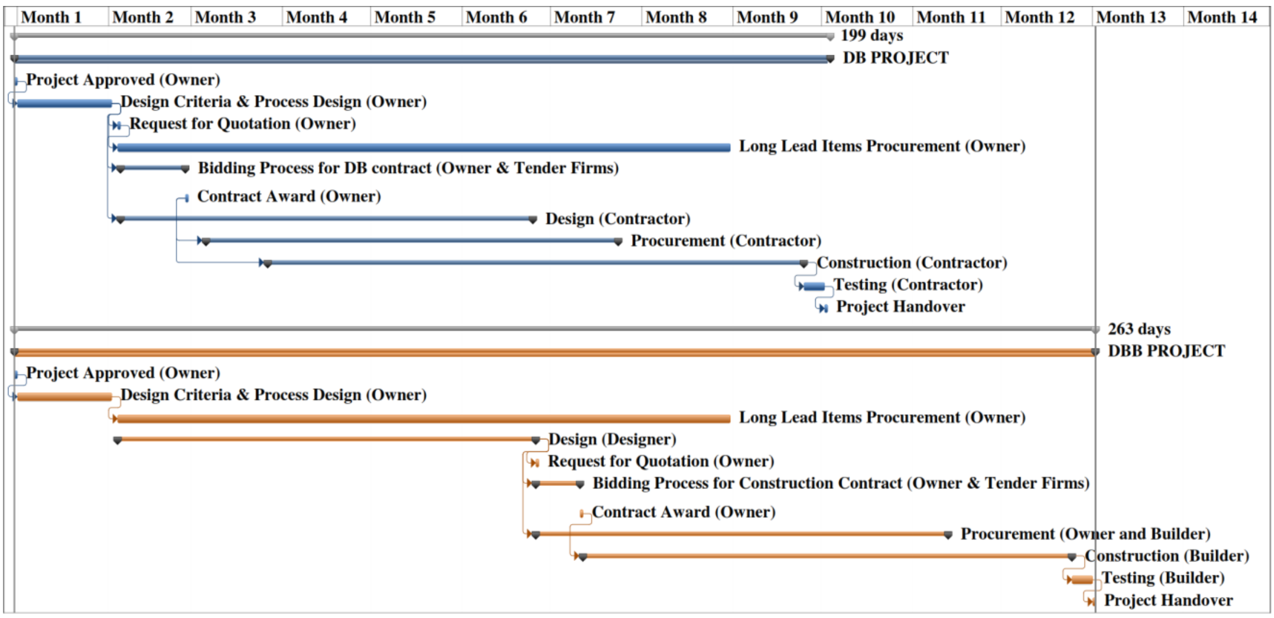

Figure 1: Timeframe Comparison in a Gantt Chart of Generic Steamfield Project under Design-Build Methodology (Blue) and Design-Bid-Build Methodology (Orange).

The owner can take advantage of the potential of the DB methodology for shorter delivery time in steam field projects, with more time to complete drilling of production or reinjection wells before committing to steamfield layout.

Design

In the example presented in Figure 1, the DBB design experiences double the time to deliver the final design drawings compared to the DB system. This situation is related to the fact that in a DBB, a designer allocates a substantial amount of resources to produce a design with the minimum risk of redesign during construction phase. A designer in a DBB contract must avoid litigious cases due to design errors. On the other hand, a DB consultant can assume risks during construction using preliminary designs. This is the case when manufacturing anchors and supports in a geothermal steamfield, which represent a low risk to the contractor when fabricating before final design is completed.

At the end of the design phase in a DB project, the design QA must be completed to comply with the agreed standards, by which time, the construction of steamfield equipment has taken a considerable portion of the project's life.

Procurement of Materials

Procurement of material (excluding long lead items such as large size valves for high pressure) is also fast tracked in a DB steamfield project. In the case of a large size steamfield contract, the pipe size is stipulated in the contract; hence, the DB contractor has the possibility to create a BoM during the early stage of the design. This advantage carries risks, which are minimised by the expertise of the Contractor's engineers. A proficient steamfield designer is capable of accurately producing a BoM with a low risk of overlooking key materials for the construction phase.

Critical long lead items can be sourced by the owner without delay while the DB contract is tendered.

Expertise Input

The experience of the team involved in the steamfield project is a significant factor that can impact on the delivery of the project. Both DBB and DB benefit from this element, nevertheless, a DB Contractor has the advantage of adding construction input from the construction team into the design. Recommendations from Contractor's construction team for steamfield equipment design are immediately available at the moment the design is approved, such as fabrication of pipelines, vessel construction, access platforms or instrument installation.

Cost-Effective Creativity

Creativity in cost-effective designs is another benefit from DB steamfield projects. A designer, regardless of the type of project methodology, uses creativity to solve project challenges, although a contractor in a DB project has the incentive to produce a design that reduces costs in fabrication and installation whilst meeting the specifications. The owner may not see these savings in a fixed price contract, but the next project will contain the cost benefits since a similar steamfield project would estimate cost based on the new cost-effective design.

Construction

As previously mentioned, construction phase in a steamfield project following a DB model starts during the preliminary design stage. Fabrication of supports, site preparation and site hazard assessment can be performed in the early stages of design, with minimum risk to the Contractor and owner. It is also possible to limit the number of manufactured or fabricated items required for the project using preliminary design drawings, and complete the last portion of those items when the final design is ready.

In a DB project delivery, the Contractor is able to evaluate the risks of starting the procurement and construction without final drawings or even during the preliminary design stage. The risk that the final design changes once construction is underway still exists; however time saved from early construction outweighs the cost of rework.

Single Point of Contact

A single point of contact for the project owner simplifies the communication load for the life of the DB works. A single Project Manager (PM) oversees the design and construction phases and their overlapping. The pattern found in the reviewed projects was that the Contractor is able to respond to unexpected changes to design and construction in a timely manner. Cross-country piping can face geotechnical challenges that require more conservative design in foundations than expected, therefore, changes to the design can be promptly communicated to the construction team.

Furthermore, in small steamfield DB projects the designer can be the (PM). This case saves costs by reducing resources utilised while the PM has a clear understanding of every technical issue.

3.3 Discussion

The generic steamfield study in Figure 1 shows that a DB project can be built in 199 days while a DBB project will take 263 days. This is a saving of 64 days or 24%.

4. RECOMMENDATIONS FOR STEAMFIELD DB CONTRACT AGREEMENTS

The legal agreement between the project owner and DB Contractor covers the scope of works and responsibilities in the development of steamfield projects. Owner and Contractor need to be aware of the contracted legal obligations undertaken. Definition of key aspects in the contract is important to maintain the expected performance delivery of the project.

The following discussion and recommendations are based on lessons learnt from a variety of DB steamfield projects successfully executed by MB Century in New Zealand.

4.1 Key Elements for an Effective Agreement for DB Steamfield Projects

P&ID

Depending on the objectives of the steamfield project, it is desired to base the contract obligations on a Process & Instrumentation Diagram (P&ID). Even if the P&ID is preliminary, this level of technical detail aids to determine requirements such as, pipe sizes, isolation arrangements, environmental discharge, process equipment redundancy, and control and instrumentation considerations.

Geotechnical conditions

Risk from geotechnical conditions of the site must be established in the contract, such as site properties, slope stability, water table and thermal gradient. The owner may choose to carry out a geotechnical assessment prior to the tender phase of the project and provide the information to the tendering companies. This case is recommended on 'greenfield' steamfield developments.

Greenfield projects commonly involve higher risks to a contractor since the area can have many unknown variables that can affect the design and build. If geotechnical information is not available during tender, a provisional sum could be provided for detailed studies and civil works required.

In 'brownfield' projects, the contractor is more likely to assume the geotechnical risk when they have performed previous work in the area.

Acceptance Criteria

Codes and statuary requirements provide well-known criteria for acceptance in steamfield equipment. However, the owner might choose to include additional requirements to the agreement, which need to be equally well defined. For example, if additional welding inspection of piping above that required by the code is requested it is advised that Non-Destructible Test (NDT) acceptance criteria is defined.

It is best not to include terms like "best international practice" since this can be open to many interpretations. An owner might demand the best equipment regardless of the cost, but the contractor is incentivised by providing the most cost-effective reliable solution.

Third party consultants

The owner may choose to employ a consultant to review a contractor's design. This can increase the level of certainty for the owner but it also can cause delays if the contractor is not familiar with the owner's consultant design approach. Small variations in design methods or interpretations can prevent the contractor from committing to the design and cause delays.

In New Zealand, the use of a third party design verifier and equipment inspector familiar to the owner and the Contractor may provide the appropriate level of quality assurance to the design and construction in accordance with the codes and standards.

Performance Requirements

Clearly defined and reasonable performance requirements for steamfield design and construction are required.

Performance criteria for steamfield can consist of:

- Design and fabrication codes of compliance
- Acceptable pressure drop in geothermal fluid conveyance
- Suitable steam quality delivery

Design and fabrication codes are well defined.

Performance Requirements – Pressure Drop

Pressure drop in the geothermal fluid delivered to a power plant is critical since economics of the steamfield and wells are directly related to this parameter. The project criteria in a steamfield design may define a strict pressure drop limit; therefore, a DB contractor needs to select a diameter pipe size that minimises the risk of exceeding the pressure drop. The contractor's pipe size selection is likely to be larger than the owner's expectations, impacting the estimated cost in the project's business case. If the owner knows the pipe size required for the project, this becomes the design criteria rather than selecting piping based on pressure drop measurements.

In two-phase piping, performance criteria by pressure drop measurement can implicate many variables. As well as line pressure, steam water flow needs to be measured. Furthermore, the error band from various instruments involved in the measurement can accumulate and increase the error band of the readings, making the pressure drop measurement meaningless.

Therefore, it is more practical to agree on a pipe size rather than request a pressure drop criteria in the project.

Performance Requirements – Steam Quality

This requirement is applicable to steamfield separators. A method of measuring steam quality and carry over in separators needs to be agreed by the owner and the contractor. While two-phase separators have been used for years in New Zealand, measurement of the steam quality is not yet standardised.

Both parties in the contract must understand that separator performance and steam quality must be considered in the context of method and location measured.

Separator performance is affected by the flow regime upstream of the vessels, which cannot be controlled by the contractor and is difficult for the project owner to measure.

Undefined Engineering Details

Contracts can exclude some items for later agreement. For example the owner may wish to leave out access platforms until they have seen the contactors piping design.

Insulation Installation

Insulation of geothermal piping can be completed after commissioning of a project. This work does not require the shutdown of the operation; in fact piping without insulation with process flow at operating conditions can serve as an in-service or on-line test for the welding QA verification.

It is important to remember that installation of the insulation during plant operation requires a higher level of HSE management.

Boundary Definition

In a geothermal power plant project, a clear demarcation of work boundaries between power plant development and SGS development is critical to define the scope of works. As previously mentioned, in this type of project, the owner manages both areas with different contractors.

Physical piping boundaries should be defined at anchors. The steamfield contactor can install Control and Instrumentation (C&I) devices with the same hardware as the plant and define termination points. Programming and HMI is best carried out by the power plant contactor.

5. CONCLUSION

The Design-Build (DB) methodology has been successfully implemented in New Zealand geothermal steamfield projects. The analysis of completed steamfield projects under DB methodology show that DB contracts have benefits that allows a steamfield project to be completed in a shorter time compared to a traditional Design-Bid-Build (DBB) approach.

Identified benefits in steamfield projects delivered under a DB method are:

- Project delivery time lower than the traditional DBB methodology.
- Procurement of material from early design.
- Construction input provided by the fabrication and construction team, potentially offer a positive outcome to the cost and delivery time.
- Cost-effective creativity in design in order to reduce cost in manufacturing and installation.
- Single point of contact that allows response to unexpected design changes and construction in a timely manner.

The discussion in the study also identified the following key aspects in a steamfield DB contract that are recommended to address prior to agreeing on delivering a project: Process & Instrumentation Diagram (P&ID), geotechnical conditions, acceptance criteria, third party consultants, undefined engineering details and performance requirements, and boundary definition.

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