Turbomachinery Project Execution for High CO_2 Gas Field: Challenges and Obstacles

Harris Abd. Rahman Sabri, Abd. Rahman Abdul Rahim, Wong Kuan Yew, and Syuhaida Ismail

Abstract—**Turbomachinery is the heart of any platform, which generates power and compresses gas. However, the current practices of turbomachinery are entangled with various challenges and obstacles, which eventually affect the overall performance of the platform. Hence, this paper aims at appraising the challenges and obstacles in turbomachinery project execution for high CO_2 gas field. Via the literature review, this aim is achieved via its objectives of 1) reviewing the oil and gas industry in terms of its operation and project execution; 2) determining the basic attributes of turbomachinery as well as the challenges and obstacles entangling its execution; and 3) proposing the solutions to these challenges and obstacles. It is found that stabilized process requirement and constant flow; subsurface uncertainties; production decline; selection process; specification and standard variations; contractual delivery; human factor; after sales support and services; and expenditure are listed as amongst the challenges and obstacles in executing turbomachinery project for oil and gas. The findings of this paper would technically contribute to the project management elements of turbomachinery project execution and assist the management team particularly on the client/consultant side in efficiently and effectively manage the turbomachinery project execution via the prediction of challenges and obstacles.**

Index Terms—**Challenges and obstacles, high CO_2 gas field, oil and gas industry, turbomachinery.**

I. Introduction

Turbomachinery is among the most critical components in any of the oil and gas platform operation. According to [1], turbomachinery is identified as a critical path in majority of project execution. Hence, the effective and efficient execution of this turbomachinery project is very much focused by the project management team in ensuring that overall deliverables of the turbomachinery project is as per the requirement of the international oil and gas industry standard and practices. Since there is currently no standard guidelines and framework in managing the execution of turbomachinery (except for technical standards and guidelines as well as general installation of turbomachinery), this paper is materialized in appraising the challenges and obstacles whilst executing the turbomachinery project so that these can be minimized or solved accordingly.

Therefore, this paper initially discusses the overview of the oil and gas industry, consisting of its various operations as well as its typical project execution. Subsequently, the discussion on the turbomachinery is taken into place, followed by the main body of content of this paper i.e. on the challenges and obstacles commonly faced by the project team while executing the turbomachinery project. Finally, the solutions to these challenges and obstacles are proposed before the conclusion of this paper is made.

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II. Overview of Oil and Gas Industry

In many of the countries producing their own oil and gas via their energy industry, oil and gas industry contributes significantly to the growth of their economy. For instance, oil and gas are an important factor to Malaysia's economic growth, constituting about 20 per cent of the nation's Gross Domestic Product (GDP) [2]. In Malaysia, oil and gas industry is observed by this paper as one of the most important sectors affecting the performance of other economy sectors by taking into advantages as being the most demanding, challenging and exciting engineering and technological advances which interests the engineers at large. The substantial development of the oil and gas industry has piloted to the evolvement of various gigantic companies including PETRONAS, Exxon-Mobil, Shell, Murphy Oil, Nippon Oil and Amerada Hess.

In general, oil and gas industry is multidisciplinary in nature. Hence, the input and contribution of every discipline of engineering throughout the processes of the oil and gas platform procurement have paramount roles to play in the industry. Due to its unique requirement, the oil and gas industry around the globe, including Malaysia, has developed standards and practices. Many of these standards and practices have been developed over time in meeting the ever demanding clients and public expectations.

With a larger demand for gas and new technologies which has make the oil and gas industry become financially attractive, numerous industry players ranging from Original Equipment Manufacturers (OEMs), service providers and contractors have emerged. All of these players have diverse range of interests in the development of these oil and gas resources. Therefore, there is a need to develop a support base that can handle the challenges of maintaining the performance of both these industry players as well as the equipment handled by these players.

A. Operations in Oil and Gas Industry

In general, there are two types of operations in the development of oil and gas industry: 1) upstream operation

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and 2) downstream operation. These operations differ in terms of execution, budget, technical constraints and economic impact.

The upstream operation focuses more on the exploration and production of the oil and gas. It involves all the oil and gas activities, which are taking place prior to processing and refining of hydrocarbons [3]. The upstream operation is observed by this paper as the most critical operation to be improved given that it is the first ever operation traditionally developed in the oil and gas industry.

The upstream operation is further divided into two categories: 1) greenfield development and 2) brownfield development. The greenfield development involves the development of new field whereas the brownfield development takes into account redevelopment and extension of an existing field.

On the other hand, the downstream operation is undertaken at the on-shore location where the oil and gas will be further refined to become sub-products, namely petro-chemical plant, oil refinery, petroleum by-products, gas processing plant, gas transmission station, petrol station etc. The types of operations in the development of oil and gas industry are simplified in Fig. 2.

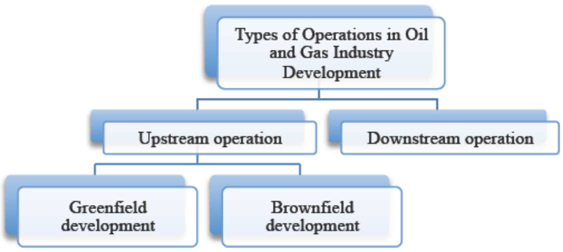

Fig. 1. Types of operations in the development of oil and gas industry.

In general, the offshore facilities should fulfillfour main functions [4] as illustrated in Fig. 2. The first function is to provide a platform, which wells can be drilled and wellheads can be supported. The second function is to provide for the dehydration of the gas and liquid stream. As for the third function that is providing adequate metering facilities for reconciliation purposes. Finally, the forth function is to provide accommodation and life support for operation and maintenance personnel, where this function is materialised by the living quarters. Turbomachinery is one of the main solutions to ensure that the offshore facilities are able to meet these functions.

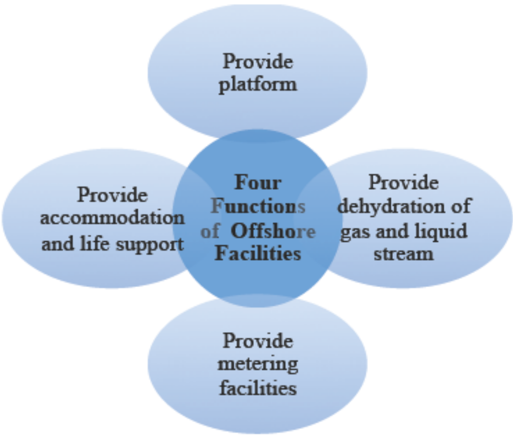

Fig. 2. Four main functions of offshore facilities.

B. Typical Project Execution in Oil and Gas Industry

Project execution in the oil and gas industry involves five different phases as summarized in Fig. 3, namely 1) conceptual phase, 2) feasibility study phase, 3) detailed design phase, 4) material procurement phase and finally, 5) construction or start-up phase. In accordance with [5], these phases are varying between organizations and projects, yet the actual processes are quite similar in nature.

Fig. 3. Phases in oil and gas project execution.

In the conceptual phase, the project execution is initiated by determining the concept for the field development. Various development scenarios will be tabled out and the most optimum solution will be selected for further deliberation during the next phase. With reference to [6], the product life cycle cost should be considered as part of the selection.

The engineering is carried out during the detailed design phase, where the engineering is being detailed out based on the specification and requirement of the clients. The main deliverables also include the Approved for Construction (AFC) drawings.

Once the details of the material and equipment requisitions are developed, the next important milestone would be the procurement phase, which also includes material and sourcing activities. Depends on the nature of each project, some of the procurement processes might start earlier and hence overlap with the engineering stage, which is also known as Front End Engineering Design (FEED) or detailed design. This is due to the fact that this paper observes that turbomachinery is quite well known as one of the long lead items in the oil and gas project development.

The next phase is the construction or fabrication of the offshore platform or plant. This involves a lot of physical activities including fabrication of structures, pipings, electrical and instrumentation works; installation of equipment into its location; pre-commissioning and also proper preservation. If the facilities are located onshore, the start up/commissioning phase will also be part of the construction works.

For offshore oil and gas projects, additional phase involved prior to the start-up/commissioning phase would be the installation of the platform, where the platform will be towed away from the fabrication yard to its designated location. Once properly installed, the work will be continued with hook-up and commissioning activities in order to obtain the final deliverables of the project.

It is noteworthy to underpin that the turbomachinery involves in each of the aforementioned phases, hence is deliberately discussed in the following section.

III. Introduction to Turbomachinery

Turbomachinery is regarded by this paper as the heart of any platform. The non-existence of the turbomachinery leads to the impossibility of the platform to function and eventually fail the operation of the whole platform.

Turbomachinery definition, according to [7], is a turbine driven package utilized to drive either a compressor train or an electrical generator. These requirements can be differentiated between mechanical drive and generator drive. A typical turbomachinery, or sometimes known as a turbo-compressor package is shown in Fig. 4 and Fig. 5.

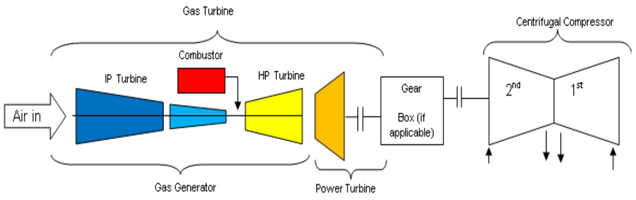

Fig. 4. Schematic of turbomachinery package.

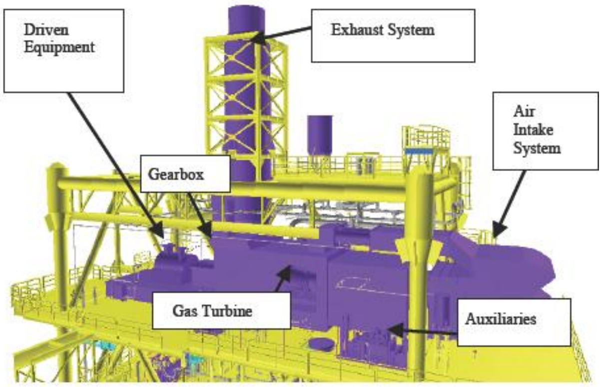

Fig. 5. Graphical representation of turbomachinery package.

As far as the oil and gas industry is concerned, there are two main functions of turbomachinery. The first function of turbomachinery is as the mechanical drive to process and compress the gas by boosting up the pressure to allow for transmission or to comply with a specific process requirement.

Generator drive is on the other hand is the second function of the turbomachinery. Through this function, an electric generator is driven to generate electrical power for the specific platform/plant.

IV. Challenges and Obstacles in Turbomachinery Project

The challenges and obstacles in the turbomachinery execution can be seen in many aspects. As for the operational aspects, among the challenges and obstacles in the downstream operation areto achieve its more stabilized process requirement and constant flow.

In addition, for the upstream operation, the challenges and obstacles consist ofthe issues on variable flow and fuel gas quality. However, since the upstream operation is further categorized into the greenfield development and brownfield development, it is worth-discussed by this paper the challenges and obstacles entangled within these two developments.

For the greenfield development, the challenges and obstacles are its issues in managing subsurface uncertainties, cost, procurement, process flow, proper material selection, fuel gas quality, flexibility and sparing, whilst in the brownfield development, the challenges and obstacles are recorded as production decline issues resulting in lower production profile that lead to turbomachinery design flexibility, specifically for the mechanical drive equipment.

However, in a bigger picture, this paper is intended to discuss the general challenges and obstacles in the execution of turbomachinery project. The first major challenge and obstacle identified are the technical and process requirement for turbomachinery selection. In order to optimize the overall project cost, the project management team should avoid from over sizing the turbomachinery as it will lead to excessive power and lower efficiency. However, if the turbomachinery is under size, it will also create a problem as there are additional changes and modification works need to be done at site. If such situation occurs, the overall development cost might be increased due to the additional works required at site. The process requirement and compressed medium composition are also vital to ensure that the correct metallurgy is chosen.

The vast differences between the Technical Specification and the Original Equipment Manufacturer (OEM) Technical Deviations also lead to the challenge and obstacle in turbomachinery project execution. The challenge and obstacle also emerge when the comparison is made between the client company's standard, worldwide accepted standard such as American Petroleum Institute (API) as well as the OEM In-house Standard.

As highlighted by [1], most of the technical issues are actually not related to the core machinery design, yet the issues linger around piping and instrumentation requirement. In addition, it also includes the electrical and control. In general, OEM will undertake exceptions from world recognized standard and even Client Company Standard. If client insists for the OEM to comply with those requirements, it will usually come together at a premium additional cost.

Vendor Data Review (VDR) and Vendor Data Incorporation (VDI) are also regarded by this paper as among the challenge and obstacle of the turbomachinery project execution. This exercise requires good collaboration between Client, OEM and Design Consultant to determine the tie-in points between the turbomachinery package supplied by OEM and interface with the whole facilities design. This includes the interconnecting piping tie-ins, cables, structural supports, design of material handling study and overall accessibility.

Nowadays, it has become a trend during the detailed design phase where the design consultant will conduct the dynamic simulation to determine whether there is an additional requirement of hot gas or cold gas bypass line in order to protect the turbomachinery from damages due to large piping volume needed to be catered. The dynamic analysis can be done by either the design consultant or even the turbomachinery OEM. If such requirement is anticipated, it is advisable to include it as a part of procurement specification in avoiding unnecessary changes.

In addition, the human factor, such as manpower and capability of the client, OEMs, Engineering Consultant, fabricator, Hook Up Commissioning (HUC) contractor; local capability building, transfer of technology, competency, migration of skilled local manpower to Middle East etcalso affect the turbomachinery project delivery.

Besides, skid size/dimension, weight, maintenance accessibility and material handling are also noted by this paper as challenge and obstacle in the execution of the turbomachinery project.

On the other hand, after sales support and services (localization programme, obsolete spare parts and long lead delivery for critical spares) also cause difficulty in executing the turbomachinery project.

On top of that, the capital expenditure (CAPEX) and operational expenditure (OPEX) (Total Cost of Ownership) are also listed by this paper as the challenge and obstacle in executing the turbomachinery, not only during execution of turbomachinery project, but also during OEM comparison and turbomachinery. During the OEM comparison and turbomachinery, CAPEX and APEX are amongst the critical criteria to be selected. In addition, [8]indicates that there are three relevant factors that should be also taken into accountsuch as equipment unavailability which leads to opportunity loss and unscheduled shutdown; fuel costs that also depends on geographical location and driven by market factors; and finally the cost of spare parts. For older turbomachinery, there is a possibility of some of the spare parts are no longer in production. All of these challenges and obstacles are summarized in Table I.

TABLE I: CHALLENGES AND OBSTACLES IN TURBOACHINERY PROJECT

	Challenges and Obstacles in Turbomachinery Project
1	Technical and process requirement for turbomachinery selection
2	Differences between the Technical Specification and the Original Equipment Manufacturer (OEM) Technical Deviations
3	Vendor Data Review (VDR) and Vendor Data Incorporation (VDI)
4	Human factor (manpower and capability of the client, OEMs, Engineering Consultant, fabricator, Hook Up Commissioning (HUC) contractor; local capability building, transfer of technology, competency, migration of skilled local manpower to Middle East etc
5	Skid size/dimension, weight, maintenance accessibility and material handling
6	After sales support and services (localization programme, obsolete spare parts and long lead delivery for critical spares)
7	Capital expenditure (CAPEX) and operational expenditure (OPEX) (Total Cost of Ownership)
8	Equipment unavailability

V. PROPOSED SOLUTIONS TO CHALLENGES AND OBSTACLES

Based on the challenges and obstacles while executing the turbomachinery project discussed in the previous section, this section highlights the proposed solutions, which may assist the project management team to effectively and efficiently execute the turbomachinery project.

Amongst the solution to the challenge and obstacle in executing the turbomachinery project is to perform a proper design by selecting the most optimum design, which includes some flexibility by covering various operating cases. This is to minimize the potential of compressor bundle re-wheel/retrofit, which is quite common for brownfield projects or after years in operation. For greenfield projects, the main issue remains on the subsurface data uncertainties. Another key factor in selecting an optimum turbomachinery design is by obtaining a balance between available driver power, the compressor characteristic and the overall process system behavior [9].

According to [10], there are a few approaches available to be implemented in order to improve expediting the process. At the same time, these approaches are also applicable in managing the turbomachinery project. These approaches consist of 1) implement strategic alliance rather than once off purchase; 2) continuous appraisal of project development between client and OEM; 3) initiate a "pre-award meeting" by starting to engage with potential OEM during early stage of engineering in order to obtain necessary basic engineering data/assumption; 4) break the project into specific milestone, by adding a critical milestone which requires client presence at OEM place, such as design review, critical testing etc.

In addition, [5] propose that an inspection on the equipment is also necessary before the material is procured. This is based on a case study of Gallegos Canyon Unit (GCU) Compression Project, where the engineering and operation personnels visited the compressor shop to inspect the equipment and suggest any modifications before the delivery to the field.

Apart from technical knowledge, it was identified by [8] that in terms of manpower involved directly with the package, they should be able to demonstrate business awareness, project management and networking skills as a very important skill, as underlined by Chartered Institute of Purchasing and Supply (CIPS).

As highlighted by [11], there are numerous justified suppliers that fall under categories, which are classified as innovators. Therefore, it is vital for the operating company to continue a good working relationship with the suppliers in long term to guarantee a successful growth strategy. The characteristics encompass 1) the ability to provide a wide range of equipment; 2) specialized performance characteristic; 3) improved performance and monitoring; 4) size and weight criteria; as well as 5) material specification.

In addition, this paper also suggests that continuous product upgrade due to technology advancement should be promoted by the OEM through research and development as a part of initiatives in confronting the current challenges and obstacles entangling the turbomachinery project execution.

VI. CONCLUSION

This paper has successfully achieved its objectives of 1) reviewing the oil and gas industry in terms of its operation and project execution; 2) determining the basic attributes of turbomachinery as well as the challenges and obstacles entangling its execution; and 3) proposing the solutions to these challenges and obstacles, which is beneficial as the practical reference to professionals involved directly and indirectly in the execution of turbomachinery projects for high CO_2 gas field. It is expected that for future studies, the important variables in successfully managing the turbomachinery projects obtained from those turbomachinery professionals based on specific case studies could be ranked in adding relevant information to the current turbomachinery body of knowledge.

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