Jafurah Gas Plant Train Concept Philosophy: A Scalable Approach for Modern Gas Facility Design

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Abstract

With the rapidly changing scenarios of gas plant design, choosing the best possible setup is important for operational, economic, and sustainability goals. Historically, gas plants have been built out in an "off-the-shelf" modular design, but the advent of the train-based concept design breaks away from the past. This paper analyses how JAFURAH Gas Plant, by implementing the train concept of philosophy, gains more in flexibility, progressive implementation and resource utilization.

The train concept moves away from the conventional centralized architecture and results in the development of flexible, scalable, and cost-effective systems that can accommodate changing industry needs. More than just a passing trend, the train-based approach reflects a strategic transition in station design-supporting enhanced operability, decreased complexity, and long-term viability in a competitive energy marketplace.

Keywords: Design Improvement, Project Management, Project Management Structures, Gas Trains Design

Introduction

The Strategic Unconventional Gas Initiative is a government action plan of Saudi Arabia to exploit its unconventional hydrocarbons. The project requires the construction of gas surface facilities to produce, process, and transport gas for increasing in-Kingdom electricity and energy requirements. The move complements the Kingdom's long-term efforts towards energy diversification, sustainability, and national economic growth.

Jafurah Phase01 Drone Photo, Figure.1

Jafurah Basin Overview

The Jafurah Basin, located in Eastern Province, Saudi Arabia, is one of the largest unconventional gas resources in the region. It extends across both the North and South fields and offers significant development potential. The proposed infrastructure comprises the Jafurah Gas Plant (JFGP), which is a standard gas plant module: inlet facilities, condensate stabilizer section, Acid Gas Removal, dehydration, NGL, and a sales gas compressor. There is also an ISF (Industrial Support Facility) and a network of upstream infrastructure like flowlines, trunk lines, and GCPs (Gas Compression Plants). These systems are constructed to deliver well fluids from the well to the process facility for separation of gas and liquids and are transported through transmission pipelines to the JFGP to be treated.

Jafurah Gas Plant (Train01), Figure.2

Scope and Purpose of the Study

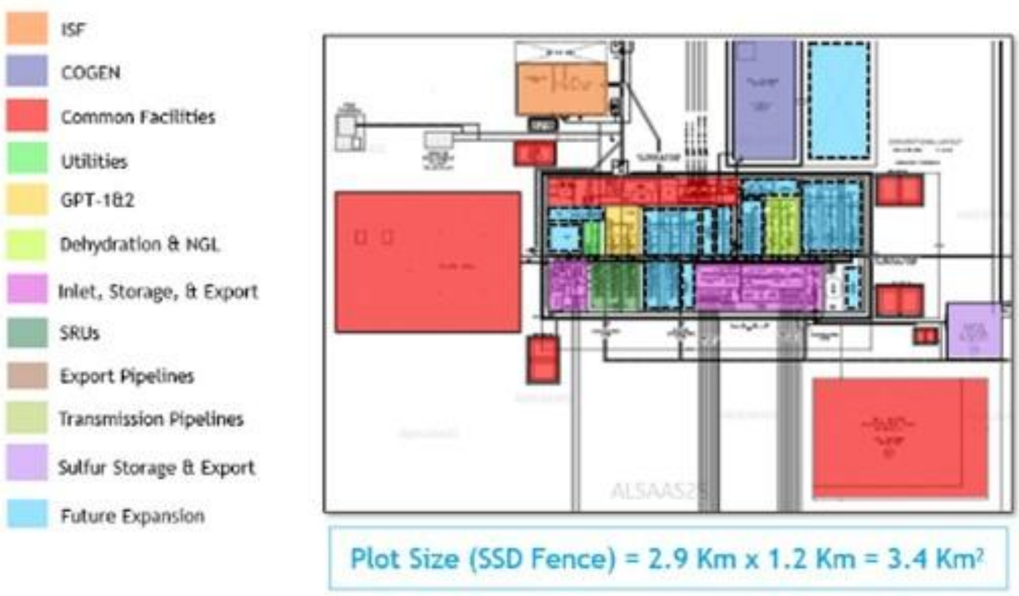
JFGP is facilities to treat gas and its associated liquids from the North and the South Jafurah fields. One of the significant concerns to be determined in the design of the environment includes an appropriate layout that will support future scalability and create a strict separation of concerns for the features and the execution process. Two main groups of configurations were studied: the classical modular configuration, with pools of the same kind of process units, connected to each other in series and from which the product flows, and the train configuration, a set of parallel independent process trains. If the train idea has been chosen, the facility will be built as a modular and staged process.

This section explains why it would be so easy to adopt for the Jafurah project with well-regarded advantages, such as design simplicity, phased construction, future expandability, being among the most notable considerations in concert with Unconventional Resources Program strategic intent.

Layout Design Philosophy

Identifying the appropriate layout philosophy is critical in defining the production plan, operational effectiveness, and long-term scalability of a gas plant. At JFGP, two design concepts have been considered: the traditional modular design layout and the train concept layout. Both approaches have their engineering justification and consequences in terms of construction, operations, and expansion planning. The modular design concept in gas plants is usually arranged by centralizing similar process units (e.g., gas treatment, stabilization system).

The modules are interconnected with shared headers that direct flow through the different stages of processing. Each cluster of units is treated as a process block, including shared inlets and outlets, and it is the normal approach to define them as one-unit operation risk area. While this method is established, it is considered complex. The use of common headers and manifolds adds to unit interdependence, so changes or outages in one area can affect the performance of others. Besides, since these headers must be sized in advance and designed to accommodate later capacity undertakings, this may result in overdesign and underutilization in the early stages.



Gas Plant Modular Plot Plan, Figure.3

In the case of train concept design, the process units needed for gas treatment and condensate stabilization are designed in independent “trains.” Each train is a standalone processing unit, capable of being operated without the need for a common process header. A train provides, on average, 50% of the total plant capacity, and full capacity is obtained by duplicating like trains in parallel.

Such design allows clear operational divisions, low complexity, and phased operation ease. It also eliminates the requirement for oversized common infrastructure and accommodates compact plot sizes. Compared to modular types, the train concept can minimize the number of buildings (e.g., substations, PIBs), interconnecting piping, and operational manpower and thus enable better efficiency in the areas of engineering, procurement, and operations.

JGP Plot Plan (Train Concept) Figure.4

Both design philosophies were compared at minimally equivalent throughputs, site limitations, and project schedules. Confirming the capital cost of each option and making a “like to like” (or “apple to apple”) comparison. All the design parameters of each discipline (Process, piping, electrical, and civil) are critically examined based on the same design assumptions & specifications.

The evaluation included process flexibility, scalability, constructability, and risk distribution at the operation stage. Equipment and process specifications were kept the same for both choices to make a fair comparison. The site evaluation did not include non-process infrastructure like administration buildings, roads, and building laydown areas. Terrain limitations and detailed utility routing were also not considered in this step. Main process units and utility systems related to central gas processing activities were prioritized.

Process Evaluation

Analysis of layout philosophy highlighted effects and key components Process evaluation. This section describes the inlet system configurations and its functions, the primary process headers, equipment arrangement, and utilities for both conventional type and train type layouts.

In traditional designs, liquids from upstream plants are led to central inlet manifolds, from which flow to processing units is directed through mutual headers. This method necessitates strong designs of manifolds with isolators to control flow re-direction, flushing, and cleaning.

In a layout where inlet works are carried out by train, the works are shared so that each train receives direct flow from its own inlet manifold. This parameterized configuration minimizes inter-train dependencies, enhances maintainability, and eases the isolation process. It also improves system robustness as the offline status of one train's inlet system does not affect the availability of other trains.

In the prior art, the main process headers have been the central flow arteries linking like units throughout the plant. Oversized headers, which often require a thorough analysis of the hydraulics to achieve balanced flow and avoid process upsets, are the norm. Train-based structures do away with the notion of shared process headers. All of the trains have their own internal piping for liquid transfer to avoid cross-train influence. This greatly simplifies header design and associated construction and commissioning risk, as well as minimizing the impact of operational upsets.

In traditional configurations, process equipment is segregated by type across centralized locations, leading to longer interconnecting piping lengths and convoluted equipment access ways. This can cause delays to the delivery of equipment and can impact the construction sequence. Packaging of equipment in each train module is facilitated by the train-based configuration, achievable as self-contained systems. This modularization allows for sequential construction, precutting work, and phased commissioning. Individual train equipment is easier to install, test, and commission, resulting in better schedule adherence and less clutter on site.

Engineering Evaluation

The engineering evaluation considers the impact of the train-based layout on core engineering disciplines vs. traditional modular layouts. All contribute to making the constructability easier, operations less complicated, and more carried to phased work. The technical effect of introducing a train concept in the Jafurah Gas Plant is the focus of this section.

Control and Instrumentation

In the traditional configuration, through an integrated system, interconnected sets of process units throughout the plant have used central control rooms for monitoring. This complicates the instrumentation wiring and the systems integration, and often, centralized systems are not easily identifiable and expandable during future modifications.

The train layout allows DCS to be made train oriented, yielding better signal segregation and easier instrumentation loops and cabling distances. One hundred and twenty-five trains can run on their own without disturbing other trains if there is a failure at a localized control. This saves the labor of expansion and enhances the reliability and maintainability of the system.

Civil and Structural

Traditional modular systems: larger foundations and building image shows dimensions of modular Iterhouses (left) and standard Iterhouses (right). 30 areas because of the integration of process equipment and interconnecting headers. The civil portion includes these larger pipe racks, long cable trenches, and common utility corridors, among other things – creating more construction work and traffic volume.

The train idea, however, leads to a more condensed block plan. The railcars are designed with a degree of self-containment that reduces the demand for large amounts of common infrastructure. Foundation, pipe rack, and support structure sizes are both within the boundary of each train, in a modular civil execution approach and by increasing site logistics during construction.

Electrical

Traditional designs center on sending power through different process units using a centralized substation, with a lot of cabling, duct banks, and voltage drop control over long distances. If there is a power cut or work being carried out on central systems, several units at a time may be affected.

But with the train idea, electrical systems can be put in the corners. Each train can receive incoming power from standalone, dedicated substations, or MCC (Motor Control Center) buildings with local energization and protection. This train load electrical arrangement allows for easier power supply, shorter cable runs, as well as enables ease of maintainability and power autonomy

Telecommunication

Telecom systems (e.g., fiber, CCTV, PA/GA, and emergency communication) are run in common corridors and linked to a central control room in a centralized arrangement. This makes systems more interdependent and complex when system expansion or re-routing is needed.

The train configuration allows individual telecom loops to be installed per train, minimizing complex cross-train equipment fitting. Telecom Equipment Cabs, Cameras, and Field Equipment may be designed by track for rapid installation and easier troubleshooting. It additionally provides that the installation of new trains remains minimally detrimental to the communication system(s) of any pre-existing systems.

Plot Plan Development & Piping

One of the significant benefits of train philosophy is related to the plot plan as a whole. The modular design requires a larger footprint for shared infrastructure, headers, PIBs (process interface buildings), and interconnect piping. This leads to higher B/L (battery limits), more coverage by a substation, and increased operating personnel. In the train layout, curve layouts are dense and can be repeated again and again.

Each train is developed within the limits of its own envelope and with replicable and safe clearance. This design cuts the full-line footprint, streamlines material flow, and improves safety by isolating hazard areas. New trains are easy to incorporate with little rework on the existing site — more execution-friendly and more cost-effective in the long run.

Conclusion

Application of a train-based design concept in Jafurah Gas Plant represents a strategic departure from the conventional approach to modular design layout. By arranging the processing units as self-contained trains that can be operated independently, the project benefits significantly in terms of scalability, constructability, and operability. This methodology also significantly simplifies engineering design in all fields and minimizes the interdependency between the systems and the capability of phased, efficient execution of the system without degrading safety or capability. The examination of process systems, utility developmental aspects, and discipline impact assessment concludes that the train concept is technically feasible and beneficial to meet the Unconventional Resources Program's (URP) long-term development plan, and in turn, reducing the JGP Phase 1 CAPEX by 25%. As energy demands and project complexity continue to rise, the train-based layout provides a forward-looking solution that enhances project delivery and sets a new standard for future gas processing facility

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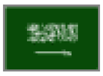

Abdulrahman Alsahlawi, an Engineer with a background in Civil & Environmental Engineering, graduated with honors from King Fahd University of Petroleum and Minerals (KFUPM). He began his career in the Project Management Office (PMO), where he supported portfolio planning, contractor performance evaluation, and digital reporting dashboards. He then transitioned to a mega project team, contributing to the Jafurah gas development, where he applied his expertise to implement digital construction tools, enhance field execution, and streamline progress tracking. His passion for innovation and commitment to construction continue to fuel his journey in the industry.

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He began his career as a Project Engineer at KAPSARC, where he successfully managed the Mechanical, Electrical, and Plumbing (MEP) scope during the construction phase. Currently, he contributed to the development of the Jafurah gas plant, having been involved since the detailed design stage and continuing through procurement and construction.