The Development of Shale Gas Modularized Surface Engineering

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Abstract. Shale gas is one of the most important unconventional natural gas, which is an effective clean energy and has bright future. However, because of the characteristic of shale gas reserve, the conventional construction mode cannot be used to explore shale gas. With the development of 3D design software, the modularized engineering is gradually becoming the solution. The standardized engineering plays a key role to promote developing level of modules by several ways. These standardized modules can be transferred and reused in other wells. The whole project can be assembly design with standardized modules. The information technique is also applied into module engineering to improve the efficiency of operation monitoring and control. The shale gas surface engineering project is becoming like product, and it will cause a new evolution of project management and shale gas exploration.

1. Background

Blue Paper of China Oil and Gas Industry Development Analysis and Prospect Report (2018-2019) was published on March 23\(^{rd}\) in Beijing. According to Blue Paper, 2018, China had consumed more than 2800×10\(^{8}\) m\(^{3}\) natural gas, which had increased 18.1% compared with 2017; 2018, China had imported 1254×10\(^{8}\) m\(^{3}\) natural gas, which had increased 31.9% compared with 2017, and accounted for 45.3% of total consumption. China has surpassed Japan to be the largest natural gas importer in the world. On the meanwhile, China government and whole society have been working on a coal-to-gas switch activity in Northern China to confront with the disturbing air pollution. Due to the industry and energy structure, this activity will be a long and continuous task that means China natural gas consumption will keep increasing at a fast rate in future.

However, the abroad natural gas supply is not stable. Northern China had suffered severe shortage of natural gas supply in the winter of 2017, one of the reasons is the natural gas supply from Middle Asia was not increased with the demand. To guarantee stable and sufficient natural gas supply, Chinese gas leading company has been investing more resources on domestic natural gas production, especially unconventional gas, shale gas, etc.

China sits on the 1\(^{st}\) recoverable reserves of shale gas in the world, more than 36 trillion m\(^{3}\), whereas contrast to American shale gas reserve, most of rich shale gas is stored in hill land such as Sichuan, Chongqing, Hubei and Guizhou Province. It means much more cost and effort has to be paid to cope with worse transportation, narrow construction site, rainy climate and environment protection. Even more, comparison with conventional natural gas recovery, shale gas exploit has faster well pressure drop and gas capacity reducing \(^{[1]}\), and it means single shale gas well cannot be extracted as long as conventional gas well. The shale gas surface engineering investment shall be much lower than conventional gas, if not, the whole project will loose economic feasibility. The shale gas surface
engineering also has to fit the fluctuation of well condition, and it is difficult to design a plant with fixed gas condition.

In fact, the conventional gas surface engineering construction mode (stick-built) cannot figure out the above mentioned difficulties with a rational and practicable investment. Though meanwhile, as a new and modern construction mode, modularization has been successfully employed in building, bridge, nuclear and offshore petrochemical engineering to achieve better schedule, cost and quality targets. Can modularization be the best answer to explore shale gas in China?

2. The Application and Development of Modularization

2.1. The origin and development process of modularization in oil and gas industry

Actually, modularization has been used in oil and gas surface engineering since 1970’s. At first, engineers and craftsmen tried to prefabricate some structure and pipes before installation to promote efficiency and quality; and then vendors began to assemble equipments, pipes, valves, cables and accessories on one steel foundation; after that, more and more equipments was supplied in set with skid or container; after engineers realized the benefits of skid equipments, they innovated engineering philosophy to develop modularized design.

2.2. The introduction of modularized engineering

The whole plant is divided into many modules with function, process and structure. Engineering would be organized and implemented in separate module. These modules could be fabricated and assembled parallelly in different workshops; needless to say civil work can also be carried out on site at the same time. These completed modules could be transported to site, and then installed with each other to form an integrated shale gas processed plant in shorter schedule, better quality and lower cost. Most important of all, and it transfers most of the site construction work to modern workshop, significantly mitigates the negative impact from shale gas surface engineering site and environment. The module size can be customized made in line with the transportation route and tools to accommodate the narrow and rough road among hill land area in Southwest China.

2.3. The key technology of modularized engineering

Honestly speaking, the modularized engineering cannot come true without 3D (three-dimensional) design software. The horizontal and vertical layout of pipes, equipments, structure and cables inside module will be a disaster, if engineering proceed with traditional graphic mode. The engineers have to describe and optimise every detail inside module before the module starts to be fabricated. Any change shall be absolutely avoided after the module manufacture is finished, because any tiny change will cause a large number of sequential changes to different modules, and it will seriously threat the project targets. Contrast with the conventional stick-built mode, the modularized engineering requires much more accurate and precise engineering and control work, since many work process concurrently.

With the help of 3D design software, engineers can conduct multi-disciplinary collaborative design to share design information interactively and simultaneously. 3D design software enables engineers to practice collision check among every component in the module to promote the engineering quality greatly. The 3D design model also can be used to carry out constructability and operation review to enhance the connection between engineering, construction and operation.

All in all, 3D design software is the most important technology to bring modularized engineering into the reality. Based on that, driven by the shale gas exploration tight schedule and investment, standardized engineering is gradually becoming the new engine of modularization. As the modern information technologies flourish, more and more advance internet and communication idea and technique are introduced into modularized project to enhance the operation efficiency, HSE and lower human resources and management cost.

3. The Prompting of Standardized Engineering
Standardized engineering and 3D collaborative engineering changed the method and knowledge accumulation of traditional engineering, both of which improved the quality and efficiency of modularization [3]. The main content of standard engineering is as follow:

3.1. Standardization of the design data and component
Secondary exploration on design software can be used to standardize and digitalize the field, expressive mode, unit, content of the design data along with the technique of database. Standardized material coding database, standardized component database and 3D module database form the foundation of modularized engineering [4]. All the databases can accumulate the similar data of different projects and convey all the data to sequential project in the manner of standardized data. The traditional engineering relies on the accumulated knowledge of engineers and graphic drawings, however, standardized engineering sets all the pipes, fittings, valves, pumps and instruments in a standardized digital way, and all the properties of each component has been fixed at the meantime, such as the inlet and outlet pressure, diameter, material, pressure drop, type of seals and drives and so on, shown as figure 1. All the properties stored in the database as data and can be utilized in the 3D design platform, which improves the efficiency of engineering significantly. All kinds of components will be coded generally, which form the foundation of the application of the design achievement in procurement and construction.

![Figure 1. Standardized components.](image)

3.2. Standardization of the rules, guidance, procedures, philosophy and design platform
Standardization of the design rules, guidelines, procedures and philosophy form a completed system, which ensures the consistency of the format and meaning of the design documents and achievement. Design platform mainly consist smart P&ID platform and 3D model platform, all the design data can be circulated employed through this platform, which promotes the co-design of different disciplines and improves the quality and efficiency of designing. It is an effective way to promote the developing levels of modularized engineering through standardization of excellent achievements from successful cases.

3.3. Standardization of modular unit
Standardized design achievements like PIDs and 3D modules which were successfully applied could be further optimized to generate standardized modular unit. Once a series of standardized engineering achievements formed, engineer can directly invoke these standardized achievements to complete the
engineering work without paying attention to the details inside of module. For instance, China Petroleum Engineering & Construction Corporation developed a series of skid-mounted and modular equipment and unit, such as three phase separator skid, metering & pressure regulating skid, chemical injection skid, compressor skid, integrated wellhead unit, TEG dehydration unit and so on. All these skids and modules are developed with the engineering practice and the feature of process of shale gas surface facilities. These standardized modules can be combined and reused according to the demand of modular engineering, shown as figure 2. These standardized modules particularly well fitted for the rolling developed or experimental shale gas exploiting. The construction and commission of the

![Figure 2. Sulphur recovery unit assembled by 23 modules](image)

projects can be realized in a very short time when using these modules, and it means much shorter payback period and better cash flow, which makes these modules very popular in middle-and-small scale investors. Standardized modules played important role in the exploration of shale gas in North America and in the product capacity construction for shale gas in Southwest China. Moreover, because these standardized modules can be transferred and reused in different shale gas wells, even module equipment leasing business is generated, which saves more direct investment, lowered the threshold of shale gas industry. And this is one of the main causes for the booming development of shale gas in America[5].

3.4. Fast assembly design
Along with the progress of standardized modular, the engineering gradually develop to a higher level, the most typical way is fast assembly design[6]. The fast assembly design means engineer can design a shale gas plant with these standardized modules, which have different function, such as pressure regulating, throttling, heating, separating, dehydration, decarbonisation, and desulphurisation shown as figure 3. Utilizing these standardized modules, the complicated engineering process could be simplified greatly. The fast assembly design might be the future engineering method, as though the specific procedures are going to be detailed and optimized.
4. Cases
When China National Petroleum Corporation (CNPC) exploited Changning shale gas block in Sichuan Province, engineers determined “two-stage station distribution” surface engineering system, which consist of well site-gas gathering station-dehydration station, formed standardized and modularized engineering. Well site unit is standardized wellhead module, which can be transferred and reused in another well. Till now, about 30% of wellhead modules have been reused since 2015. With the progress of rolling development, more and more wellhead modules will be reused. The gas gathering station is assembled by 11 independent and standardized modules, shown as table 1. These modules also can be portable and reusable.

**Table 1. Modules forming gas gathering station.**

| S/N | Module name                  | Module function                                        |
|-----|------------------------------|--------------------------------------------------------|
| 1   | Wellhead module              | Wellhead ESD, pressure & temperature remotely transferring |
| 2   | Wellhead grit catcher module | Grit catching of shale gas from well                   |
| 3   | Heating furnace module       | Heating & throttling of shale gas from well             |
| 4   | Metering & separator module  | Gas-liquid separating & metering of shale gas from well |
| 5   | Production separator module  | Gas-liquid separating                                  |
| 6   | Alcohol injection module     | Inhibiting of hydrate generating                       |
| 7   | Gas pressure regulating module | Gas separating & regulating                           |
| 8   | Compressing module           | Centralized compressing of shale gas from well         |
| 9   | Caustic tank module          | Storage of produced water                             |
| 10  | Manifold module              | Metering & processing manifold                         |
| 11  | Pig launcher module          | Pipe pigging                                           |
The dehydration station is designed as a series of standardized and modularized unit, one is $15 \times 10^8 \text{m}^3/\text{a}$, another is $40 \times 10^8 \text{m}^3/\text{a}$. Both of the two kinds of unit is assembled engineered with standardized modules. Comparison with similar capacity conventional gas plant developed by traditional construction mode, the modularized engineering attained excellent achievements, shown as table 2.

**Table 2. Achievements of modularized engineering.**

| contents            | effects                        |
|---------------------|--------------------------------|
| Floor area          | Reduced by 30-40%              |
| Schedule            | Shorten by 30-50%              |
| Welding quality     | FTQ promoted to above 99%      |
| Investment          | Reduced by about 5%            |
| Staffs              | Reduced by 20-30%              |

5. Conclusions and outlook

The shale gas surface engineering project is becoming like a big product, with the standardized modules replacing the traditional equipment, material and construction. This product is assembled with many modules, which can also be regarded as products and can be produced in modern workshop. It means the shale gas construction industry is developing into one part of modern manufacturing industry from handicraft industry.

To the shale gas surface engineering, the product feature is gradually becoming more than project feature, and it will cause a series of evolution of project management and exploration management. Undoubtedly, it will be a great impetus to the shale gas exploration.

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