GOING ‘JETTYLESS’ OPENS NEW MARKETS

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As nations seek to diversify energy resources, as well as transition to a lower emission world, gas forms an increasing share of the energy mix until the shift to sustainable energy resources will be completed. Gas deliveries through regas of LNG have shown strong growth over the past decade with the bulk of these volumes delivered by large FSRU (> 2 MTPA). To enable small scale regas (0.05 to 1.5 MTPA), new concepts are needed to provide LNG to customers at a competitive and affordable price. The key challenges lie in initial low gas demand, limited available space in the existing ports with challenging metocean conditions outside driving the need for substantial marine scope including breakwater and jetties.

Shell, together with suppliers has designed a ‘jettyless’ concept, consisting of a novel single point mooring system for LNG combined with a subsea cryogenic pipeline. This paper will present the design philosophy and premises, the expected cost reduction and resulting market forecast for this approach. A case study will be presented in the paper showing how the concept is geared towards faster market access at lower cost to the customer. Though CAPEX is a key driver for these projects, the jettyless solution also should ensure high operability in challenging metocean conditions with impact on the local environment.
INTRODUCTION

As societal awareness and consensus on the impact on the environment and on human health of greenhouse gas emissions increases, the energy landscape is set to undergo a strong shift over the coming decades. The energy transition to energy sources used with reduced greenhouse emissions, is happening across the globe today at various stages, driven by a shift in local and regional policies, e.g. EU policy makers have established targets to be translated into local policy [1] or China advocating no more coal fired power stations in areas which show high air pollution. In addition, large capital investment funds consciously start to select greener energy investments as part of their portfolio management. In the background, increases in geopolitical tension also disrupt the status-quo in energy flows as nations not only seek to become ‘greener’, but also be more independent of single energy suppliers for their energy demand.

Gas, supplied as LNG, is an attractive greener fossil fuel and is available as a global traded commodity. Natural gas is a perfect partner to provide back-up for wind and solar, as battery storage develops. Shell forecasts a significant growth in LNG demand as illustrated in Figure 1, this is mainly driven by complementing domestic / pipeline supply as well as substituting coal and liquid fuels for existing demand in emerging countries. Also, Shell is driving and expecting a growth in use of LNG both as a marine and truck fuel.

A significant portion of the demand increase will be served by several larger infrastructure projects, likely to be executed in the form of Floating Storage and Regassification Units (FSRU) or large-scale LNG import terminals. Having emerged only in 2008 as a technical solution for LNG import, there are now over 40 FSRU projects in operation with several more under construction. This accounts for ~ 12% of the global LNG trade today, equal to a demand of 35 MTPA in 2017 [2]. Commercially though, due to the large capital investment required to build an FSRU (even converting an existing LNG carrier) and the site-specific infrastructure costs, these projects struggle to be viable for demands well below 1 MTPA. The resulting cost of gas (or power derived from gas) cannot compete with traditional liquid fuels such as heavy fuel oil.

Figure 1 - Shell LNG Outlook till 2035, [2]
For island nations with a small power demand (typically < 300 MW) or large industrial users looking to cut emissions, a small LNG terminal can be more competitive against existing fuels. In this paper’s context, “small scale” is referred to as a demand or output between 0.05 MTPA and 1.0 MTPA. Based on the forecasted market growth and recent and historic opportunities, Shell estimates that 50+ MTPA of the LNG demand growth could be developed through these smaller terminals. These small-scale terminals may also include LNG bunkering facilities in support of the growth of the use of LNG as a marine fuel or industrial users.

Key challenges for small-scale projects lie in initial low gas demand, e.g. due to staged conversion or absence of a local gas transmission grid. In addition, limited available space in existing ports and possibly challenging metocean conditions outside the ports require a jetty and breakwater. Jetties and breakwaters have a considerable impact on the CAPEX (capital expenditure) of small scale regas terminals as well as could have a significant environmental impact. Therefore, new concepts are needed that do not require an expensive jetty or breakwater, these concepts will be referred to as “jettyless” in the remainder of this paper.

**CONCEPT SCREENING**

Therefore, a screening study was conducted to indicate the most promising single point mooring (SPM) system for small scale onshore LNG regas facilities. SPM systems are widely used for various tanker sizes mainly for offloading of crude oil; whereby fixed or floating systems are applied. SPM systems are not in operation for LNG offloading to date, as such the flexible aerial or floating hoses and cryogenic swivel form the key challenge for the system, both from a technical and cost point of view. All other components of an SPM system are expected to be available. The study examined a wide number of types of SPMs, through a high-level selection analysis based on costs (CAPEX and OPEX), environmental impact, Safety and security, Technology maturity (assess through the technology readiness level) and operability. A total of 16 systems were evaluated, consisting of conceptual designs and existing systems. Examples of conceptual jettyless designs that were included are floating systems, submerged systems and fixed tower systems as illustrated in Figure 2 and Figure 3. Existing jettyless systems that were evaluated include the HiLoad system by Sevan, the Autonomous Transfer System (ATS) by 7Seas, and the jettyless solution by Connect LNG.

![Figure 2 - CALM subsea hose systems](3)
The application window of the SPM considered design water depths from 10 m to 15 m for a maximum vessel draft of 8 m for a 20,000 m³ LNGC. Today, there is a limited fleet of small-scale seagoing LNG carriers in the range of 7,500 – 20,000 m³ available and most of these vessels are on long term charter, and only operational in a single region. Existing LNG carriers (large scale) are equipped with mid-ship manifolds at the side of the hull which will present challenges for an SPM. As a base premise for the SPM for small scale regas, it is deemed acceptable to create a new design with a bow-loading manifold, which could also be designed as a retro-fit unit for existing smaller ships. This would result in shorter offloading hose lengths which should be beneficial from a cost and safety perspective. In view of the regional operations (‘milk run’) model for small scale regas, dedicated vessels may form the most effective commercial model.

A non-exhaustive list of the considered functional requirements is listed below:

- Marine operational conditions based on LNG carrier moored with the design environmental conditions (metocean and seismicity) using the 1-year return period (RP) maximum conditions. The significant wave height limits are set to 2.6 m for 15 m water depth.
- Survival conditions based on SPM system during the design storm using the 100-year RP maximum conditions
- Ability to offload up to 1000 m³/hr of LNG within the marine operational conditions
- LNGC discharge pressure: 4.5 barg, maximum pressure drop across the SPM system: 3 barg
- The SPM system is expected to be located between 400 m and 2500 m offshore. A subsea cryogenic pipeline will connect the SPM to the onshore facility. This pipeline will be a looped system and LNG is circulated continuously in between operations.
- Type C tank systems are assumed on the small-scale LNG carriers – no vapor return pipeline to shore.
- SPM system designed to be normally not manned, with power provided from shore (cable) – possibly supplemented with local renewable energy sources. Personnel access for maintenance and inspection through boat landing.
- SPM system should be designed to perform in line with existing LNG carrier practices to ensure safe and smooth (dis)connection, purging, ESD verification etc. (SIGTTO guidelines). The typical connection frequency is estimated at once every 1-2 weeks.
- Design life of 25 years with a minimum availability of 98%, which may include weathervaning.
LNG carrier collision with the SPM system should not result in release of hydrocarbons.

A relative ranking for the concepts was established based on the criteria worked by a multi-disciplinary group in Shell. This identified a fixed tower like system either equipped with aerial hose or marine loading arm in combination with bow manifold tankers be the most credible solution for offloading LNG through an SPM system.

This concept has been dubbed ‘jettyless’ – referring to the absence of a jetty. Following the conclusion of the screening study, Shell engaged with several contractors to further design the SPM system in a pre-FEED stage to mature the technical solution. Based on their initial response, Bluewater Energy Services and SBM Offshore were selected to develop the SPM system together with Shell and they concluded this work over the course of 2018. The development program was guided through an initial joint Hazard Identification (HAZID), technical definition work by the contractors to reach a pre-FEED stage maturity based on the functional requirements and further clarification with Shell on safeguarding, process control, LNG carrier interface and hull definition (through Shell Shipping and Maritime division), etc. Once all work was completed, a multi-disciplinary review session was held focused on key technical risks, confirming the systems can be selected by projects going forward to enter FEED. It also identified which key risks still require further assessment, one of which is extended aerial hose qualification which was kicked off late 2018.

In parallel other technologies are being worked to lower costs for small scale regas. For example, the use of floating hoses with a small floating structure to connect to the LNG carrier has been successfully developed and deployed by Connect LNG in Norway late 2017, [4]. For applications near to the shore where the presence of floating hoses in the water does not present a safety concern considering maritime traffic, this solution also offers a cost-effective LNG delivery mechanism.

GOING JETTYLESS – SINGLE POINT MOORING TOWERS

The program’s vision is illustrated in Figure 4, moving from a jetty and trestle-based approach today with cryogenic piping towards a subsea cryogenic pipeline combined with a fixed loading tower with aerial hoses. Figure 5 shows the two developed concepts, which on first appearance are quite similar but are based on different technologies to offload and have different operational and safeguarding philosophies, e.g. in terms of purging and start-up. Both systems are scalable with regards to water depth up to 25 m, can be integrated with different cryogenic pipeline technologies and offer a high operational uptime in a wave exposed environment. The designs can be further modified during FEED based on additional local requirements, e.g. hurricane conditions or the local geotechnical conditions impacting on the foundation. Preliminary installation philosophies have been established considering the full delivery of the marine scope, so including the cryogenic pipeline installation, integration and commissioning of the system.

After initial developments in existing ports (relying on present civil infrastructure), the reduced CAPEX with operational flexibility and smaller environmental footprint of the proposed SPM systems is expected to result in increased market uptake. Based on a portfolio review of the LNG regas projects globally worked by Shell over the past 3 years, the SPM system would be applicable for most of the small projects (albeit not always as a base case
due to for instance a very small LNG demand or available port quay wall access) and is therefore now consistently considered in the screening process for any of these future opportunities. Based on contractor feedback, further cost reductions can be achieved through standardization and regional replication, which further becomes attractive in clustered LNG regas developments such as in South East Asia or the Caribbean.

![Figure 4 - Jettyless vision](image1)

![Figure 5 - Developed SPM systems by Bluewater Energy Systems (left) and SBM Offshore (right)](image2)

**CASE STUDY**

Based on the pre-FEED definition, cost and schedule estimates have been defined for the SPM systems. To illustrate the economic impact of the jettyless concept, a case study is presented on a project in South-East Asia which was looking to secure market access for a 0.7 MTPA LNG regas demand. The distance to shore from the selected LNG tanker mooring location was 1200 m. A small-scale LNG regasification plant was designed based on standard components to cater for this demand, and various import configurations were developed targeting sufficiently high operability. The metocean study results indicated a breakwater would most likely be required to provide sufficient availability to the jetty combination. Figure 6 presents an overview of the key identified concepts with the breakdown into the major scope items: storage (onshore or offshore), the onshore plant scope and the maritime scope, which includes the mooring, breakwater, jetty/trestle or SPM structures. The results are shown in
relative CAPEX (in %) compared to concept 2 which is a conventional jetty and trestle connected with an onshore LNG regas facility with onshore storage.

1. FSU storage with jetty and trestle with breakwater and LNG regas plant
2. Jetty and trestle with breakwater, with onshore tank and LNG regas plant
3. Jetty and trestle without breakwater, with onshore tank and LNG regas plant
4. SPM system with subsea pipelines without breakwater, with onshore tank and LNG regas plant
5. SPM system with novel subsea LNG pipeline without breakwater, with onshore tank and LNG regas plant

Figure 6 – Cost breakdown of onshore LNG regas plant with different (marine) offloading facilities

As illustrated, an overall cost reduction of ~30% can be achieved by moving away from a jetty/trestle-based solution with breakwater to a SPM system without breakwater and using cryogenic pipelines. If we consider only the marine scope, the cost reduction is over 57% when moving towards an SPM system. In this example this equates to 50+ million USD CAPEX saved on this small-scale LNG regas project which is clearly an enabling step. It also reduces the schedule to execute and build the facility by taking away the requirement to build a breakwater (which can add >6 months offshore execution scope including all the surveys and engineering work) by using the SPM system which relies on well proven foundation technology (piling) and a pipeline pull-in installation.

This paper is focused on the marine scope of small scale regas – and as shown in Figure 6, other components such as storage and the LNG regasification equipment itself contribute to a major part of the CAPEX. Further improvements in these areas are also under investigation by Shell and various project teams, by e.g. using different storage technology compared to the standard atmospheric double containment tanks and a more modular approach / designs which rely on heat integration with a power plant. By also further reducing these infrastructure costs, Shell believes small scale LNG can truly be unlocked, even at scales below 0.25 MTPA. Leveraging the market and joint development with suppliers is a key strategy forward which Shell looks to replicate as new technologies are being considered.

FUTURE DEVELOPMENTS

Concept 5 listed in Figure 6 is an example of another innovation Shell is working on with suppliers. Shell holds the patent on a composite fiber-reinforced material which is suitable for cryogenic service to transport LNG. Shell identified a manufacturing method (laser-welding) to make pipelines out of the material and is currently developing this further with key suppliers as a next step to lower marine infrastructure costs. This concept lowers costs compared to the conventional metal-based LNG pipeline solutions (which rely on expensive Ni alloys) due to a lower base material cost and an easier on-site fabrication/installation. During 2019 the first phase of this
development is scheduled to be completed. In a second phase the goal is to develop a full cryogenic pipeline including thermal insulation.

The fiber-reinforced composite material was identified through material screening, and a suitable technology has been identified to manufacture the pipeline based on this material. Using the composite material should allow development of a cryogenic pipeline at low cost which has a smooth inner bore and is light weight. This would enable long distance transport and set this solution apart from the cryogenic flexible and floating hose developments which rely on a corrugated stainless steel inner surface. The developed liner solution could be integrated within existing technologies; once the technical challenges on handling the high thermal contraction, and the design of the end coupler to integrate with existing metal flanges are resolved.

CONCLUSION

This paper presents the development of the jettyless concept by Shell, together with two contractors, whereby an LNG single point mooring system has been designed through pre-FEED level of definition. This development is in line with the goal to lower CAPEX costs for small scale regas facilities (0.05 to 1.0 MTPA) by simplifying the marine infrastructure while maintaining high operability. Through a case study, the relative cost impact has been illustrated to be ~ 30%, which is due to a reduction of ~ 57% of the total marine scope costs (equating to over 50 mln USD CAPEX saved). Though CAPEX is a key driver for such projects, the jettyless solution also has less impact on the environment, thus fitting in with the energy transition to energy use with reduced greenhouse gas emissions. This paper also presents an outlook on future cost reduction opportunities for this concept, driving forward a pathway to cheaper LNG availability, e.g. by using a composite subsea pipeline. Shell looks to integrated solutions developed with or by the market to help lower costs on the onshore regas plant and storage to further deliver clean fuel to communities across the globe.

REFERENCES