AN INNOVATIVE SOLUTION FOR FIXED OFFSHORE LNG REGASIFICATION TERMINALS

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ABSTRACT

Several developments are currently underway to add offshore LNG regasification options to the natural gas supply portfolio. Offshore LNG regasification systems generally fall into two main categories, fixed or floating. While offshore LNG regasification systems may appear to offer many advantages over onshore systems, they also introduce new challenges, risks, and uncertainties into the LNG supply chain. Whereas offshore oil platforms have a long track record, the concept of offshore LNG regasification is quite new and thus has new considerations in terms of environmental issues, floating operations and floating LNG offloading. The offshore LNG regasification terminal may be a continuous baseload facility with significant storage of LNG. A floating solution may look very attractive from the initial investment point of view, but the leasing of such infrastructures is so high that their reliability in the long term, and for baseload operations, is very limited. There are many considerations for siting offshore LNG regasification terminals, including shallow water or deepwater locations, coastal or deep offshore locations. Final designs depend on distance from shore, marine environment, type of soil, pipeline availability, and market area. Foster Wheeler is developing an innovative offshore fixed concept for LNG regasification which is a reliable alternative for the current floating solutions, as its execution schedule is similar to the FSRUs and with a much lower overall cost. This ideal solution can be attractive for those projects in which a low investment cost and short schedule is needed, and where there are land constraints.

1. INTRODUCTION

Foster Wheeler believes, along with many others, that the projected growth in gas demand, and specifically where LNG imports are needed to meet that gas demand, will translate into the requirement for faster execution of LNG regasification terminals.

In this paper we present a new design for an LNG regasification terminal which can meet aggressive schedules and is flexible in terms of site selection.

2. OBJECTIVES

The objective of this paper is to outline a solution for LNG regasification projects where the client’s objectives may include:

- Developing a terminal that achieves commercial operation in two years, typically 22 months
- Using floating storage units in lieu of LNG tanks to accelerate the start-up date avoiding a potentially protracted permitting process, which is often experienced for onshore terminals
- Potential onshore sites are not physically feasible or require large investment, such as extensive dredging, to make the site acceptable
- Low operating costs

One solution to meet the above objectives is a floating storage and regasification unit (FSRU). However, FSRUs tend to be less economic compared to traditional onshore regasification terminals due in part to the high vessel leasing costs. Foster Wheeler has developed a LNG regasification terminal concept in which
execution schedule is competitive to those offered by the FSRU providers, and with a much lower capital cost.

3. DEVELOPMENT OF THE CONCEPT

3.1 Design Choices

Offshore LNG terminals can be fixed (sea island jetty, jacket, GBS.) or floating (Floating wharf (metal buoys fastened to anchor chains) and weathervaning) from a structural point of view. The selected “support” technology is very important, since it has a large impact on investment and operating costs, flexibility, safety, availability and reliability, time for completion, etc.

Moreover, in order to select a suitable technology it is necessary to consider several factors such as location characteristics (climatic conditions, sea water depth, etc.), storage and send-out requirements, environmental issues, etc.

The following options were considered:
- Floating storage regasification Unit (FSRU)
- Floating storage unit (FSU) + floating regasification unit (FRU)
- Gravity-based structure

3.1.1 FSRU

This solution consists of a vessel, new or reconverted from a carrier, equipped with tanks for LNG storage and with all the required vaporization process equipment. The FRSU’s main components are:

- LNG transfer system (offloading system),
- Storage tanks, (in ship)
- Boil-off gas (BOG) handling system,
- LNG pumping system,
- Vaporization equipment,
- Delivery facility, and
- Auxiliary systems.

In the FSRU the LNG delivered by LNG carriers is received by the FSRU offloading system, stored in tanks, pumped, regasified into natural gas and delivered to consumers through a flexible or rigid riser, connected to the subsea pipeline or via high-pressure loading arms fixed on a jetty. Prior to its delivery, the natural gas flow rate is measured by an ultrasonic flow meter and the gas is odorized.

The following scheme describes the principal components of an FSRU

![Figure 1: Process Block Scheme]
This sketch illustrates three possible means of LNG vaporization:

1) Open Loop Seawater: pumping warm seawater across the vaporizer and discharging cooled seawater
2) Closed Loop Water: pumping fresh water through a closed circuit in which the water is warmed in the FSRU boilers and cooled across the LNG vaporizer
3) Closed Loop Steam: Using steam produced in the FSRU boilers to vaporize the LNG and returning the condensate back to the boilers in a closed loop

3.1.2 FSU+FRU
This alternative is based on providing two different vessels, one to function as LNG storage and the other as the regasification unit. This solution is best suited to calm waters. The overall process is similar to the scheme shown in Figure 1.

3.1.3 Gravity-Based Structure LNG Terminal
This solution consists of a pre-cast caisson structure developed to receive LNG carriers. The structure includes internal LNG storage tanks and all required regasification equipment is installed on the caisson superstructure. LNG carriers moor on this structure as it is equipped with all required nautical equipment (quick release hooks and a fender system) and unloading/process equipment (unloading arms, vaporizers, etc.). Quick release hooks are devices intended for safe mooring of large tankers, allowing quick release by the control room in case of any incident.

Experience shows that this is a very expensive solution and delivery of the structure, including the storage tanks, can be very protracted, meaning that this solution cannot meet accelerated schedules.

3.2 Foster Wheeler Solution
Foster Wheeler’s solution actually combines features of the three concepts outlined in 3.1 above, and is designed to be modular and scalable.

In summary, Foster Wheeler’s solution consists of a regasification unit, permanently moored to an LNG ship which acts as the FSU. A gas pipeline connects to onshore receiving facilities supplying the gas to the local pipeline grid. This configuration enables a permanent installation to be put in place at a competitive price and fast schedule, while the availability of the plant is higher than the regasification vessels alternatives since there is a lower impact from adverse sea conditions.

In more detail, the offshore facilities consist of the following elements:

- A conventional LNG carrier modified and classified to function as a FSU that will be moored to a platform which also acts as Jetty.
- Jetty/Platform with all the facilities for mooring ships (LNG carriers and the FSU). Ships will be moored on opposite sides of the jetty and LNG transfer will be carried out using the unloading arms installed at both sides of the jetty.
- Offshore facilities and regasification equipment installed on top of the platform

Figure 2 shows the added value of this solution to the Client.
Figure 2: Curve of Value

<table>
<thead>
<tr>
<th></th>
<th>Foster Wheeler Solution (FWS)</th>
<th>Leased FSRU</th>
<th>Onshore Regas and LNG tank</th>
<th>Onshore Regas with FSU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial CAPEX, $Million</strong></td>
<td>160 (based on caissons)</td>
<td>70</td>
<td>300</td>
<td>180</td>
</tr>
<tr>
<td><strong>Total Investment, Net Present Value (10 years) (including OPEX)</strong></td>
<td>173</td>
<td>541 (Including FSRU charter rate)</td>
<td>324</td>
<td>194</td>
</tr>
<tr>
<td><strong>Optimum Schedule, months (up to Mechanical Completion)</strong></td>
<td>16 (based on caissons)</td>
<td>18-20 (considering that FSRU has to be built)</td>
<td>36</td>
<td>22</td>
</tr>
<tr>
<td><strong>Permitting</strong></td>
<td>Quick schedule</td>
<td>Quick schedule</td>
<td>Long schedules</td>
<td>Long schedules</td>
</tr>
<tr>
<td><strong>Restrictions of Applicable Standards</strong></td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Potential for Standardization</strong></td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Medium (depending on vaporization system)</td>
</tr>
</tbody>
</table>

Note: This comparison is based on a storage capacity of 150,000 m³ and a send-out rate of 500 MMscfd.
3.2.1 Technical Description

The regasification unit will be constructed so that all the equipment and modules are integrated, transported and placed on a piled concrete platform, or on a concrete caisson, at the final destination.

![Figure 3: Regas Unit Module](image)

A commonly-required send-out capacity is 500 MM Scfd of gas with an additional 50% peak capacity. Foster Wheeler’s design is based on three trains, each with a send-out capacity of 275 MM Scfd, assembled together on one module. The system is configured as 3x33% regasification trains. The module contains the required pumps, motors, heat exchangers, instrumentation and control systems, and interconnecting piping between the trains. Target gas outlet pressure is 33-95 barg at the module edge. Turndown capability for each train is 100-20%.

The regasification unit is designed for handling LNG with a wide range of compositions, so can be used with almost any available gas in the LNG market.

<table>
<thead>
<tr>
<th>Component mol %</th>
<th>LNG Heavy</th>
<th>LNG Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>87</td>
<td>97.53</td>
</tr>
<tr>
<td>C2</td>
<td>8.37</td>
<td>2.16</td>
</tr>
<tr>
<td>C3</td>
<td>3</td>
<td>0.25</td>
</tr>
<tr>
<td>iC4+nC4</td>
<td>1.2</td>
<td>0.04</td>
</tr>
<tr>
<td>nC5</td>
<td>0.23</td>
<td>0.01</td>
</tr>
<tr>
<td>N2</td>
<td>0.2</td>
<td>0.01</td>
</tr>
<tr>
<td>Density @ -159.8°C (Kg/m³)</td>
<td>470</td>
<td>429</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>18.72</td>
<td>16.44</td>
</tr>
<tr>
<td>Higher heating value (MJ/Sm³)</td>
<td>42.87</td>
<td>38.42</td>
</tr>
</tbody>
</table>
The plant is designed to comply with IMO and the requirements of classification societies’ such as DNV. The system is designed and manufactured according to DNV guidance for offshore regasification installations.

When the module is fabricated in the yard, and before shipping, final leak and pressure testing is performed at the module yard. This must comply with DNV requirements. All components would have already been tested at the manufacturers’ facilities according to recognised standards and/or to the Class Societies requirements.

The plot plan is designed to provide:

- Safe escape from working areas.
- Efficient ventilation of hazardous areas.
- Minimal explosion overpressure in case of ignited gas release.
- Access for fire fighting and emergency response.
- Prevention of serious consequences from dropped objects.
- Facilitation of good operation and control in normal and emergency situations.
- Minimal possibility for escalation of fires and other failures or accidents.
- Safe containment of accidental release of hazardous liquids.
- Planned simultaneous operation.
- Easy maintenance access to all the equipment of the plant with the maintenance cranes.
- Loading arms will be designed to be compatible with the motion envelope of the FSU and LNG carrier.
- Space minimization, to reduce cost of the platform
3.2.2 Structural Design

The loading platform (including mooring and fendering system) and dolphins will serve to host the shuttle LNG Carrier and unload the cargo via arms to the FSU. The FSU will be permanently moored on the other side of the platform. Liquid cargo will be transferred from the FSU to the platform top regasification unit via LNG loading / unloading arms.

Over the piles (jackets) there are steel beams which conform the supporting structure for the platform.

The mooring dolphins and fenders have been located taking into consideration ship compatibility assessments carried out to guarantee the compatibility between the ships fleet and proposed platform.
3.2.3 Construction Approach

Due to the challenges of working offshore, the construction strategy is based on:

- Minimizing work offshore at “site”
- Minimize the construction period
- Designing for modularization

The plan is to deliver the modular plant (one module) per the scheme below, using a semisubmersible ship (float over).

![Figure 6: Float over Operation](image)

Construction process summary:

- Construction of steel/concrete pile.
- Manufacturing and pre-commissioning of module at yard.
- Load-out of module on top of a semisubmersible vessel (manoeuvred via RO-RO)
- Transport of module from yard to offshore location
- Unloading on top of the pile supports (float-off).
- Module hook-up
- Commissioning and start-up.
In this option the dolphins at one side of the platform are installed after the unloading of the module to permit the manoeuvre of the ship.

3.2.4 Alternative platform construction method

The compact regasification concept (70 x 50m.) allows a more standardised and modular civil infrastructure approach to be taken, consistent with a fast-track schedule.

Cellular reinforced concrete caissons can be used, comprising a base slab and vertical walls. The delivery period of these components enable a fast-track schedule to be achieved.
The regasification unit is placed on the caisson and they can be transported together, with the caisson functioning similarly to a barge.

Once the caissons arrived at site, caissons are ballasted down with granular material to ensure stability against metocean actions and operation loads. This can be done since part of the caisson is still open. Later, the deck slab is cast in situ.

Drivers to consider this solution versus the jacketed solution include:

- The supporting Infrastructure’s main dimensions (beam and freeboard) are conditioned by operation and survival loads i.e. equipment, berthed vessels and FSU, metocean actions, seabed conditions, as well as water depth, seabed depth

There are cases where a caisson is not adequate; typically due to poor seabed properties that limited bearing capacity or typical water depth greater than about 17 meters.

- The supporting infrastructure’s main dimensions may also be limited due to availability of pre-casting yards or yards with enough capacity to accommodate the required beam or depth, although such matter can be dealt with since caissons can be towed, so yards do not really need to be close to the site area. In this regard evaluation of metocean conditions for transportation and availability of windows is a critical aspect

- Limitations due to the size of access channels to the eventual offshore location may be harder to overcome to arrive to the project site

Figure 8: Cellular Reinforced Concrete Caissons
4. SUMMARY / CONCLUSIONS

In this paper Foster Wheeler has introduced a novel design for a fast-track cost-effective LNG import terminal with the following characteristics:

- Capacity of 500 MMScfd of natural gas send out
- Proven equipment
- Known technology
- High availability
- Able to deal with a wide range of LNG composition

Foster Wheeler’s solution includes an FSU that allows for reduction in execution time, compared with the construction of onshore LNG tanks.

Civil works, if caissons are used, are not an issue in terms of schedule. Caissons can be designed and constructed in much less time than the equipment delivery.

Caissons can be towed far away from the pre-cast yard providing a high level of flexibility in identifying the best yard location. Process skids can also be loaded on top of caissons for transportation.

Construction execution is based on proven methods, similar to any other offshore upstream facility.