Integrated approach to LNG terminal planning and design

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Introduction
With Liquefied Natural Gas (LNG) as one of the key solutions to the rapid increase in energy demand, there is a need to employ integrated planning to deal with the marine transport and terminal design issues for new LNG facilities.

At present, LNG vessels range from 65,000 cubic metres to over 185,000 cubic metres in capacity, but much larger vessels are under development. Once an LNG vessel reaches a receiving terminal, the LNG is unloaded into large tanks and stored until it is re-vaporised and piped into the natural gas distribution network. As the capital cost of the tanks is significant, there is a need to optimise the storage capacity.

Further, the marine structures at an LNG terminal may have to be designed to serve a variety of vessel sizes and configurations and the appropriate storage capacity to handle their respective cargos.

Sandwell has the tools to take an integrated approach to the design of a total marine system including: The simulation of the marine transportation, the investigation of the appropriate storage capacity at the berth, simulation of vessel operations and the optimisation of the berth itself. This paper summarises Sandwell’s approach to LNG terminal planning.

Transportation simulation
The planning of an LNG terminal is complex and its design needs an integrated approach to satisfy various ship/shore functional requirements adequately, as well as to minimise delays due to weather conditions.

A key Sandwell tool for terminal development is simulation of the LNG transportation system from the loading of vessels at the source, through the ocean transit conditions, to the receiving terminal and its storage system. Simulation can clearly identify cycle time variation throughout the year for each step of the LNG logistics chain and be used to optimise vessel characteristics, terminal operations, and storage requirements.

Accommodating the entire fleet of LNG vessels is desirable from a flexibility point of view; however, due to widely varying characteristics of individual vessels, this approach presents a major challenge to the terminal designer.

Simulation modeling can greatly reduce the number and type of variables that need to be considered for a proposed LNG operation and the subsequent detailed design of its marine terminal. It is the starting point for many of the projects Sandwell is asked to evaluate.
Initial terminal planning

Initial planning and site selection of a LNG marine terminal is very often governed by factors not related to terminal operations per se; e.g., land ownership, proximity of the supply or demand source, or other socio-economic factors. Thus, in most cases, the terminal planning exercise is carried out within a confined pre-determined area that may not have all of the desirable elements to develop an effective LNG terminal.

Site-specific climatic data and bathymetric survey are essential for the initial terminal planning. The climatic data, if sourced from previously collected data, are best when confirmed by site-specific measurements, even if only of limited duration. With the site-specific bathymetric and climatic data, terminal planning can proceed with two focus areas:

- Ship motion analysis
- Full bridge navigational simulation

Ship motion analysis

The ship motion analysis is generally carried out using a computer programme for hydrodynamic analysis of floating structures and their mooring systems for the site specific wind, wave and current conditions (see Figure 1 illustrating a vessel model using the AQWA suite of programmes).

A ship motion analysis permits the LNG terminal planner to optimise the berth and mooring layout and orientation, as well as to assess the anticipated ship motion due to wind, wave and current for all six degrees of freedom. This assessment then becomes the tool to determine the expected weather downtime and also to determine the limiting operating climatic conditions for a safe operation.

Full bridge simulation

Full bridge navigational simulation is done using a computer-aided real-time simulation facility to ensure that approaches to, and departure from, the proposed terminal would be safe, as well as to develop weather threshold and safety parameters for the terminal operations. The simulation also determines the tug requirements and checks the viability of the mooring system. There are a number of facilities that can be used for navigational simulation. A properly planned and executed ship motion analysis and navigational simulation programme generally will lead to an optimised terminal layout, which can be further developed to meet the operational requirements.
Ship to shore interface

The major elements to be considered for the ship-to-shore transfer are the mooring and berthing systems, loading arms, gangways and firefighting capabilities.

The provision of an effective mooring and berthing system is of paramount importance to the design of an LNG terminal. Larger LNG vessels are being developed to keep pace with the growing demand of LNG worldwide and carriers up to 250,000 cubic metres are being designed. Along with these new vessels, consideration needs to be given to the existing fleet of the operating vessels.

The terminal design requires in-depth understanding of the details of each LNG vessel’s characteristics, including the on-board manifold location and the parallel body dimensions, as well as how each vessel will behave with regard to wind, wave, and tide conditions at each site. Unfortunately, the vessel design parameters that affect the terminal layout are not standardised.

The terminal layout can become further complicated when both the port-side-to and starboard-side-to approaches are to be considered. The most effective approach to develop an optimum terminal layout is to examine each individual vessel separately at the berth to ensure that relevant governing code (OCIMF, PIANC, BS Standards, TER MPOL, etc) recommendations for the mooring and berthing are maintained. While it is not possible to design a structure to satisfy the needs of every LNG vessel, each terminal’s design can be developed to maximise the number of vessels that can be serviced.

Figure 4 shows a 138,000 cubic metre LNG vessel at a proposed berth during the terminal planning stages. This illustration shows the importance of examining each individual vessel for the proposed layout – for the case above, the berthing dolphin at the right is not effective as it falls beyond the parallel body, although in plan, its location appears to be acceptable.

Selection of the fenders is another critical item for smoother operations. Conventional buckling column rubber fenders are generally economical and have very good energy/reaction characteristics. However, these do tend to amplify the wave induced ship motion and generally do not perform well in partially exposed locations. For such locations, air block fenders or pneumatic fenders with flatter load-deflection characteristics, as shown in Figure 5, are preferred.

Loading Arms play an instrumental role in a successful ship-to-shore transfer of the LNG and the arm’s envelope needs to be precisely developed to account for anticipated ship motions for the operating wave conditions, as well as to accommodate the tidal variations. Loading arms generally need a multi-layer
secondary platform for servicing purposes. Figure 6 shows an integrated structural model of a platform and loading arms on a jacket structure. Loading arms must be designed so that the swivel assembly can be positioned on the platform for maintenance purposes. Additionally, the general requirements listed in the OCIMF publication, “Design and Construction Specification for Marine Loading Arms” need to be followed to ensure operational safety, including an Emergency Release System (ERS) and a Quick Connect/Disconnect Coupler (QC/DC).

Fire fighting equipment for an LNG terminal is best located at the back end of the loading platform, one monitor at each corner, with 200% coverage of the loading arms’ area. The equipment needs to be designed as per National Fire Protection Association (or equivalent) standards and seawater is commonly used as the water source.

In conclusion
The above topics outline the critical elements for an integrated approach to the planning and design of an LNG terminal. Additional consideration needs to be given to the following to further optimise the design of the facility:

- Terminal storage volumes versus vessel sizes
- Optimising the vessels, the loading terminal and the receiving terminal as a system
- Physical modelling of the primary vessels to confirm vessel motion at berth
- Fast time simulation for approach and departure channel operation
- Discrete event simulation for the total LNG transportation chain including the design elements

More than any other bulk terminal, an LNG operation has a large measure of complexity combined with risk elements that make their design challenging and exciting to engineer.

ABOUT THE AUTHOR AND THE COMPANY

Mr. Shrivastava is a marine structural engineer with a Masters Degree and over 30 years experience in the planning, study, design and construction of marine terminals. He has extensive experience evaluating and designing both liquids and dry-bulk terminal facilities internationally. As a senior marine engineer, he has designed berths and shipping systems for all types and sizes of vessels. Mr. Shrivastava has been Project Director or Project Manager for more than 15 terminal developments, most of them new facilities.

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