

Title of the Invention

An LNG terminal

Technical Field

The present invention relates to LNG terminals comprising floating storage structures

Background Art

Construction of Liquefied Natural Gas (LNG) terminals are often complex and capital-intensive due to various reasons such as; land usage, regulatory restrictions, construction costs and time, access to resources and productivity constrains during construction, LNG storage availability and end of life de-commissioning.

Several of these problems are currently solved by employing floating storage structures. Figure 1 is a schematic representation of an import LNG terminal involving floating storage structures. This terminal involves a large finger jetty with two floating storage structures arranged on either side of the jetty. The two floating storage structures provide the LNG terminal with higher redundancy, should one of the structures be unavailable due to maintenance or down-time. The jetty also has arrangements to allow berthing of a LNG carrier and transfer systems to allow the discharge of LNG from the LNG carrier to the floating storage structures. The floating storage structures will then transfer LNG to an onshore re-gasification facility that in turn will feed natural gas (NG) to the consumers.

Deep water shorelines are considered beneficial for LNG terminals because the jetty, or quay, can be close to shore and allow berthing of large vessels without the need for changes to the seabed. Dredging the seabed in order to increase the depth of canals in the way to, or at the berth, has become increasingly difficult due to environmental restrictions and high costs. However, an excessively inclined seabed can become a design challenge because such seabed does not allow the use of conventional piling or earthing during construction.

Accordingly, the solution in Figure 1 is not suitable for steep shorelines with deep water bathymetry, such as sites in mountainous areas. In these locations, the seabed is heavily inclined and as a result the water depth increases significantly even at short distances from the shoreline. In Figure 1, the hull orientation requires a long jetty in order to accommodate the three hulls that can berth at one time. This solution is not feasible for steep shorelines with deep water or other locations that can restrict the length of a jetty, i.e. narrow channels.

Other types of jetties are also known, such as one shown in Canadian patent application publication 2842621, which discloses a LNG export terminal with a twin-hull floating storage and offloading vessel (FSO). However, this LNG export terminal requires the construction of large jetty structures around the twin hull FSOs, and such an arrangement is not conducive for use in sites with steep shorelines. In addition, by joining both hulls together, the units are not redundant and the failure in one of them can lead to a total loss of storage.

A drawback with conventional LNG terminals comprising floating storage structures is their use of converted LNG carriers as floating storage structures. Most LNG carriers are designed for one purpose only, to transport LNG from a loading port to a discharge port in the most efficient way. As a result, when designing the LNG cargo handling system on the LNG carrier, the systems are required to carry out only one operation at a time. Conventional floating storage structures converted from LNG carriers can therefore handle either loading or offloading LNG, and never both at the same time. Although floating storage structures built from converted LNG carriers are typically cheaper and require less time to build, the LNG terminal may end up with a bottleneck in operations due to their inadequacy for simultaneous loading and offloading. Such bottlenecks may lead to increased down-time and slower loading or offloading from the LNG carrier, leading to a disruption in operations at the LNG plant and a stop in the continuity of LNG production which increases costs heavily.

Furthermore, conventional LNG carriers are required to dry-dock every 2.5 to 5 years, depending on age, in order to carry out out-of-water hull surveys, as well as other requirements to inspect and/or test the integrity of cargo tanks, safety systems, hull structure, etc. The LNG carriers are required to be in gas free condition prior to entering a shipyard, and are therefore required to have means onboard that allow them to purge, inert and eventually free all cargo tanks of gas prior to arrival. For floating storage structures converted from LNG carriers, the same will apply. The floating storage structures thus require gas freeing equipment on board requiring maintenance, and replacement floating storage structures are required during periods of dry-docking, thus driving up costs.

The prior art does not show an LNG terminal with high loading and offloading capacity, availability and reliability, and simultaneously being suitable for deep water shorelines.

Accordingly, a solution for LNG terminals in deep water shorelines with improved availability and reliability is needed.

Summary of the Invention

With the abovementioned challenges and known solutions in mind, the present invention provides an LNG terminal which overcomes the drawbacks in the prior art. The new and inventive LNG terminal herein thus comprises an onshore LNG facility, at least one floating storage structure, a permanent mooring system, a jetty and a pipeline system arranged in a manner allowing for improved loading and offloading, availability and reliability, and simultaneously being suitable for areas where a long jetty is not feasible.

Thus, it may be advantageous provide an LNG terminal for deep water shorelines with higher redundancy, as it is capable of accommodating a plurality floating storage structures. Furthermore, the floating storage structures comprise of a multitude of independent storage containers, therefore issues with any one container should not affect the operability of the terminal.

More specifically, it may be advantageous to provide an LNG terminal with a jetty allowing for a plurality of floating storage structures to be arranged with an orientation that does not require the construction of long jetties, and therefore the invention is suitable for sites with steep shorelines and deep water.

Further, it may be advantageous to provide an LNG terminal with simpler floating storage structures, since means for production and distribution of electric power, utilities, controls, LNG processing and BOG collection and management are handled at the onshore plant. The floating storage structures will thus have lower building costs, as well as lower operating costs due to reduced maintenance required for redundant equipment on board the structures.

Further, it may be advantageous to provide floating storage structures which are capable of simultaneous loading and offloading from and to the LNG plant and LNG carrier.

Further, it may be advantageous to provide a system capable of isolating, purging, inerting and gas freeing any storage container on a floating storage structure without having to do the same with the rest of the operational storage containers. In this way, the floating storage structure can remain operational even if one or more storage containers are opened for inspection and/or repairs.

The present invention provides significant improvements in relation to known solutions, as an LNG terminal comprising floating storage structures with low costs, high reliability and high availability can be provided for areas where long jetties are not feasible for technical and/economical reasons.

Accordingly, the present invention relates to LNG terminal, the terminal comprising:

- an onshore LNG facility,
 - at least one floating storage structure, the at least one floating structure comprising an elongated shape with a first end and a second end,
 - a permanent mooring system for mooring the at least one floating structure,
 - a jetty, the jetty extending in a longitudinal direction from a shoreline out into a body of water and terminating at a loading jetty portion, the loading jetty portion comprising a first mooring arrangement for mooring an LNG carrier and an external transfer system,
 - the jetty further comprising at least one internal transfer system, the at least one internal transfer system being arranged at a point along the length of the jetty between the shoreline and the loading jetty portion,
 - a pipeline system adapted for transporting hydrocarbons between the onshore LNG facility, the at least one internal transfer system and the external transfer system,
- wherein the floating structure is connected to an internal transfer system at the first end of the floating structure, and where the floating storage structure is moored such that the second end is oriented in an angle substantially perpendicular to the longitudinal direction of the jetty.

The angle between the jetty and at least one floating storage structure may be defined herein as the angle defined by a line running through the center of the jetty in the longitudinal direction of the jetty, and a line running through the center of the at least one floating structure in the longitudinal direction of the at least one floating structure. A substantially perpendicular angle may be defined herein an angle diverging up to +/-30 degrees from a strictly perpendicular angle of 90 degrees between the jetty and the floating storage structure. Such angle allows the floating structures to adjust to the shoreline configuration and maintain the advantages of a short jetty.

Thus an LNG terminal can be provided in deep water shorelines or areas where a long jetty is not feasible, whilst providing for the use of low cost floating storage structures with high reliability and availability.

The jetty extends from land or the onshore LNG plant to a water body in one direction, and the length of the jetty may be considered the distance from the shoreline to a distal end,

typically the end of a loading jetty to which the LNG carrier is moored. Examples of water body include, but are not limited to, sea, lake and water channel. In the context of various embodiments, the term jetty may refer to a dock, a harbour, a pier or a structure projecting into a sea or water body for mooring, docking or berthing sea-going vessels. Examples of jetty include, but are not limited to, finger jetty, quay, and T-shaped jetty. The jetty may be T-shaped as the loading jetty may be wider than the main jetty part extending out to the loading jetty, but the loading jetty will preferably not be wider than the length of the jetty. The loading jetty's width is advantageously adapted for mooring of the LNG carrier, however the construction of the loading jetty is also subject to technical and cost considerations. A long jetty may be considered as extending up to a mile from the shoreline, and a short jetty being considered as a jetty which is too short for parallel mooring of an elongated floating storage structure, the storage structure typically being a converted LNG carrier. Short jetties may be required due to geotechnical considerations or other considerations e.g. due to insufficient width of the body of water such as in a river. The invention may be especially beneficial for shorelines where the depth abruptly increases at a short distance from shore, herein referred to as steep water shorelines, thus making long jetties difficult to build as the water may be so deep that any foundations will be technically challenging. Normally conventional pile with concrete cap jetty design is feasible to up to 30 meters water depth, for deeper waters jackets i.e. structural towers need to be used. However the cost of manufacturing and installing jackets increase significantly with their height, which depends on water depth and seabed conditions. Therefore it is desirable to reduce the length of jetties in steep or/and deep shorelines. Shorter jetties may also be preferably due to lower capital and operational costs. A shorter jetty will require less LNG piping and handling systems thus reducing costs, it will also be beneficial for operations as they are not spread out over a large area. Less LNG piping will also reduce BOG production, thereby resulting in a more efficient LNG terminal. The length of the jetty will thus be dependent on these technical challenges and economic considerations, which will be apparent to the person skilled in the art based on the requirements of the specific site for the LNG terminal and the disclosure of the invention herein.

An onshore LNG facility may be defined herein as a facility comprising means for liquefying or re-gasification of natural gas, and may further include facilities for producing, processing and/or storing natural gas. Facilities for storing natural gas may include land-based storage tanks. The term tank may refer to cargo tank, storage tank or any tank or container which is

adapted to store or carry fluid, such as LNG. The onshore LNG facility includes facilities for re-gasification and further processing of LNG, and may further include facilities for producing, processing and/or storing other liquefied gases such as LPG, CNG or hydrogen. Facilities for storing natural gas may include land-based storage tanks.

The term floating storage structure may herein refer to floating storage tank (FST), floating storage unit (FSU), floating storage and offloading (FSO) unit, floating production, storage and offloading (FPSO) unit or any sea-going vessels having one or more tanks or containers. The floating storage structure may be a monohull vessel, i.e. a single hull in contrast to the catamaran hull shown in Canadian patent application 2842621. The floating storage structure may be a purpose-built floating storage unit or converted from an existing sea-going vessel, e.g. LNG carrier. The floating storage structure may include any one or more types of tanks onboard, e.g. International Maritime Organisation (IMO) Type A, Type B or Type C tanks.

The term LNG carrier may refer herein to any receiving vessel which is to load or offload LNG depending on whether the LNG terminal is employed as an export or import terminal.

The term transfer system refers herein to systems provided for transfer of fluid between structures or systems that are subject to relative motions therebetween, e.g. jetty and LNG carrier, jetty and floating storage structure. A transfer system may include fluid pipelines, support structure for supporting the pipelines, and mechanical and/or electrical system for moving or manipulating the pipelines. These pipelines may comprise flexible pipes e.g. flexible hoses, and/or articulated connections e.g. rigid arms with swivels or bellows. The internal transfer system refers to a transfer system for onloading and offloading LNG between the floating storage structures and either of the LNG carrier and onshore LNG facility.

The permanent mooring system is configured to maintain the floating storage structures in position. Examples of a permanent mooring system include, but are not limited to, a strut arm system, piling system, wire systems, chain and anchor spread system, and pre-tensioned anchor system, etc. In some embodiments, at least part of or some components of the permanent mooring system may be provided at the jetty, thus mooring a floating storage structure to the jetty. The floating storage structures are moored to the at least one permanent mooring system to allow safe operations for extended period of time.

The floating storage structure is preferably elongated, such that it comprises a width and a length. The orientation of the floating storage structure may therefore also be described as having a width arranged alongside the jetty and having the length of the floating storage structure substantially free of the jetty. The floating storage structure will thus preferably be substantially parallel to a shoreline, or an underwater steep inclination which typically follows the shoreline. This orientation will also typically be in an angle non-parallel to the jetty. Thus, the floating storage structures may be safely and reliably moored to a short deep water jetty.

In an aspect of the invention, the at least one floating structure may comprise a second mooring arrangement for mooring the LNG carrier to the floating structure. Since the LNG carrier and the at least one floating structure will be substantially parallel, mooring lines may be used to moor the LNG carrier to the at least one floating structure.

In an aspect of the invention, the LNG carrier may be moored to at least one dolphin mooring. Dolphin moorings being defined herein as a marine structure that extends above water level and is preferably not connected to shore, and which are known in the art.

In an aspect of the invention, the pipeline system may comprise a loading system extending between the onshore LNG facility and the at least one internal transfer system. In an aspect of the invention, the pipeline system may comprise an offloading system extending between the at least one internal transfer system and the at least one external transfer system. In an aspect of the invention, the pipeline system may comprise a vapor system extending between the onshore LNG facility, the at least one internal transfer system and the external transfer system. Advantageously, the pipeline system may thus handle continuous loading and offloading of LNG and boil off gas may thus be continuously managed, collected and returned to shore. thereby decreasing occurrences of LNG processing at the onshore plant.

In an aspect of the invention, the jetty comprises at least two internal transfer systems, the at least two internal transfer systems being arranged on opposite sides of the jetty in the jetty's longitudinal direction. In some aspects, the floating storage structures may be arranged on both sides of the jetty, i.e. the jetty is interposed between the floating storage structures, wherein each of the floating storage structures may have a width arranged alongside the jetty and having length substantially free from the jetty.

In an aspect of the invention, the terminal may comprise at least two floating storage structures, wherein each internal transfer system is connected to a separate floating storage structure. The use of more than one floating storage structure provides redundancy to the storage solution, so storage is always available even if one floating storage structure is out of service.

In an aspect of the invention, the LNG terminal may comprise at least two floating structures, wherein the terminal comprises at least two floating structures, wherein at least one first floating structure is connected to an internal transfer system at a first end of the floating structure, and a second floating structure is connected to the second end of the first floating structure. Thus, should only one side of the jetty have favorable conditions for mooring floating storage structure, the terminal may still be provided with a plurality of floating storage structures for redundancy.

In an aspect of the invention, the at least second floating structure may be moored in a substantially similar longitudinal direction as the first floating structure. In aspects where two floating storage structures are provided, the floating storage structures may be arranged in tandem to one another, i.e. end-to-end or one following the other in a lengthwise direction of the floating storage structure, and may be further arranged such that the starboard and port sides of each floating storage structure are generally free of the jetty, i.e. the starboard and port sides of each floating storage structure are not arranged alongside the jetty. The floating storage structures may thus be arranged on a same side of the jetty, where a first of the floating storage structures has a first width arranged alongside the jetty length and the starboard and port sides generally free of the jetty. A second of the floating storage structures has a second width arranged proximate to the aft or forward end of the first floating storage structure and the starboard and port sides generally free of the jetty.

In an aspect of the invention, the at least one second floating structure may be connected to the pipeline system via the first floating structure.

In an aspect of the invention, the onshore LNG facility may comprise facilities for boil-off gas BOG collection and management.

In an aspect of the invention, the onshore LNG facility may comprise facilities for controlling the LNG terminal. The control facility may include devices and systems for controlling at

least some of the facilities and/or systems comprised in the LNG plant and/or near shore LNG terminal.

In an aspect of the invention, the onshore LNG facility may comprise facilities for electric power generation. The onshore power facility may include facilities for power generation, power storage facility and/or power transmission. Provision of electrical power and utilities from shore systems significantly reduces the refurbishment and conversion costs as well as the operational costs related to the maintenance of redundant equipment that would normally be onboard ships operating as floating storage structures.

In an aspect of the invention, the onshore LNG facility may comprise facilities for producing, processing and/or storing utilities, wherein utilities comprise any of: nitrogen, water, cooling water, compressed air, instrument air, heating and drainage collection. Utilities may further comprise missing inert gas, warm natural gas, firefighting means, pneumatic or hydraulic fluids or any alternative means of transferring power.

In an aspect of the invention, the jetty may comprise means for transferring between the onshore LNG facility to the at least one floating storage structure, any of: electric power, control signals and utilities. Integration of the floating storage structures with the onshore LNG plant will allow the floating storage structures to be operated from a shore main control room in the same manner as a conventional land-based tank, and drastically reduce the need of personnel onboard the floating storage structures.

In an aspect of the invention, the at least one floating storage structure may comprise a plurality of storage containers. A floating storage structure may thus comprise of a multitude of tanks or containers, therefore issues with any one tank should not affect the operability of the plant.

In an aspect of the invention, the at least one floating storage structure may comprise a cargo management system arranged to load and offload LNG from selected storage containers. This beneficially provides:

- Continuous inflow or rundown of LNG (loading) from the shore production facility (in the case of a liquefaction plant) or from an LNG carrier (in the case of a receiving plant).
- Cargo inventory management; by nominating the tanks where incoming LNG will need to be allocated into, or by internal tank to tank transfers.
- Discharge LNG from nominated cargo tanks onto a receiving LNG carrier (or shuttle vessel

in the case of a liquefaction plant) with the purpose of transporting LNG to other markets or to a re-gasification process plant.

In an aspect of the invention, the at least one floating storage structure may comprise an inert gas system arranged to provide inert gas and dry air to selected storage containers. On conventional ships, it is normally not possible to inert and gas-free some of the cargo tanks. In contrast, the invention provides an inert and gas free system that is capable of isolating, purging, inerting and gas freeing any tank without having to do the same with the rest of the operational tanks. In this way, the floating storage structure can remain operational even if one or more tanks are opened for inspection and/or repairs.

Throughout the description and claims different words and terms are used, the definitions of these and other characteristics of the invention will be clear from the following description of a preferential form of embodiment, given as a non-restrictive example, with reference to the attached drawings wherein;

Brief Description of Drawings

Figure 1 shows an existing LNG terminal configuration;

Figure 2A shows a LNG terminal configuration having two floating storage structures arranged on both sides of a jetty according to one embodiment of the invention;

Figure 2B shows a LNG terminal configuration having two floating storage structures arranged on same side of a jetty according to one embodiment of the invention;

Figure 2C shows FSOs oriented in various angles substantially perpendicularly to the jetty.

Figure 3 shows a loading and an offloading liquid system;

Figure 4 shows piping arrangement at each tank interface of a floating storage structure;

Figure 5 shows a vapour return system;

Figure 6 shows a cooldown system;

Figure 7 shows an inert gas and gas freeing system;

Figure 8 shows a LNG terminal employed as an export terminal.

Figure 9 shows piping arrangement of the jetty portion

Figure 10 shows additional piping arrangement of the jetty portion

Detailed Description of the Invention

The inventive concept will now be described more fully hereinafter with reference to the accompanying drawings.

The floating storage structures G1 are moored to the at least one permanent mooring system G8 to allow safe operations for extended period of time. In some embodiments where two floating storage structures G1 are provided, the floating storage structures G1 may be arranged in tandem to one another, i.e. end-to-end or one following the other in a lengthwise direction of the floating storage structure G1, and may be further arranged such that the starboard and port sides of each floating storage structure G1 are generally free of the jetty 4, i.e. the starboard and port sides of each floating storage structure G1 are not arranged alongside the jetty 4. In the embodiment of Figure 2A, the floating storage structures G1 are arranged on both sides of the jetty 4, i.e. the jetty 4 is interposed between the floating storage structures G1, wherein each of the floating storage structures G1 having a width 2 arranged alongside the jetty 4 and having the starboard and port sides generally free of the jetty 4. In the embodiment of Figure 2B, the floating storage structures G1 are arranged on a same side of the jetty 4. In other words, a first of the floating storage structures G1 has a first width 2 arranged alongside the jetty 4 length and the starboard and port sides generally free of the jetty 4. A second of the floating storage structures G1 has a second width 2 arranged proximate to the aft or forward end 3 of the first floating storage structure G1 and the starboard and port sides generally free of the jetty 4. Figures 2A and 2B also show mooring lines 10 connecting the LNG carrier G2 to the loading jetty 7 and floating storage structures G1.

In some embodiments, the length of each floating storage structure G1 may be generally non-parallel to the jetty length 4. In some other embodiments, the length of each floating storage structure G1 may be generally parallel to a shoreline.

Fig. 2C schematically illustrates different aspects of the angle of orientation of two floating storage structures relative to the jetty. The aspect to the right in the Figure 3 illustrates two floating storage structures oriented in a strict perpendicular angle relative to the jetty, where the angle is 90 degrees. Whilst the aspect in the left and middle, illustrate diverging aspects where the angle may diverge up to 30 degrees from strictly perpendicular. The dashed lines illustrate the centrelines of the floating storage structures and the jetty respectively.

A loading system shown in Figure 8 is provided and operative to fluidly connect the onshore plant G7 to one or more floating storage structures G1 for performing loading operations when the LNG terminal 1 is employed as an export terminal. More particularly,

the liquid loading system F1 is operative to fluidly connect the onshore plant G7, e.g. LNG facility or land-based storage tank at the LNG plant, to one or more cargo tanks G3 at one or more floating storage structures G1. The loading system F1 (or first set of pipelines) in Figure 3 comprises one or more internal transfer system for loading L5, one or more loading lines L1, one or more branch-off lines L9 and one or more filling lines L12 as shown in Figure 4.

Reference is made to Figures 3, 4 and 9 wherein each floating structure is provided with a loading line L1, one or more loading branch-off lines L9 and one or more filling lines L12. The loading line at the jetty JL1 is operative to fluidly connect the LNG plant G7 e.g. LNG facility or land-based storage tank at the LNG plant, to each of the floating storage structure's internal transfer system for loading L5. On each floating storage structure, the internal transfer system for loading L5 which is operative to fluidly connect to a loading line L1. The loading line L1 is operative to fluidly connect the internal transfer system for loading L5 to one or more branch-off lines L9. Each branch-off line L9 is operative to fluidly connect the loading line L1 to one or more filling lines L12. Each filling line L12 is operative to fluidly connect a branch-off line L9 to a storage tank G3.

In some embodiments, a loading control valve L13 is provided and operative to throttle, e.g. enable and/or modulate LNG flow or loading into any floating storage structure or isolate the floating storage structure, e.g. disable LNG flow.

In some embodiments, the internal transfer system for loading L5 may be located at the jetty. In some embodiments, the internal transfer system for loading L5 is operative to fluidly connect to the loading line L1 via a manifold. The manifold may be located at the midship or one of the ends of the vessel, e.g. bow or stern.

In some embodiments, the loading line L1 comprises of necessary piping, insulation, valves, instrumentation and controls, to allow transfer of LNG from the internal transfer system for loading L5 to any one or more tanks L4 via loading branch-off lines L9 and filling lines L12.

In some embodiments, a loading control valve L10 is provided and operative to throttle, e.g. enable and/or modulate LNG flow or loading into a respective storage tank or isolate the storage tank, e.g. disable LNG flow. The loading control valve L10 may be provided at a loading branch-off line L9, e.g. operative to fluidly connect the loading branch-off line L9 to the respective filling line L12. The loading control valve L10 may be a remote-controlled valve.

During a loading operation, the loading line JL1 receives LNG flow from the LNG plant G7 and directs the LNG flow to the internal transfer system for loading L5 of any or all

the floating storage structures. The internal transfer system for loading L5 directs flow from to the loading line L1. The loading line L1 receives the LNG flow and directs the LNG flow to one or more branch-off lines L9. Each branch-off line L9 receives the LNG flow and directs the LNG flow to one or more filling lines L12. Each filling line L12 receives the LNG flow and directs the LNG flow to the respective tank G3.

A offloading system shown in Figure 8 is provided and operative to fluidly connect one or more floating storage structures G1 to a LNG carrier G2 berthed at the LNG terminal 1 for performing offloading operations when the LNG terminal 1 is employed as an export terminal. More particularly, the offloading system F2 is operative to fluidly connect one or more storage tanks G3 at the one or more floating storage structures G1 to one or more tanks G3 at the one or more LNG carriers G2. The liquid offloading system may be further operative to fluidly connect various tanks within a same floating storage structure for transfer of LNG between the tanks. The liquid offloading system F2 may be further operative to fluidly connect storage tanks G3 of various floating storage structures G1 for transfer of LNG between these floating storage structures G1, via an internal transfer system. The offloading system F2 (or second set of pipelines) comprises of interconnecting pipelines JL2 at the jetty Figure 9 an internal transfer system for offloading L6 and one or more offloading lines L2 Figure 4 on each floating storage structure G1.

Reference is made to Figures 3, 4 and 9 wherein each floating structure is provided with a offloading line L2. The offloading line L2 is operative to fluidly connect one or more storage tanks to the offloading transfer system L6. The offloading line L2 is separate from the loading line L1 to allow simultaneous and independent loading operation via loading line L1 and offloading operation via offloading line L2. The internal transfer system for offloading L6 is operative to fluidly connect the offloading line L2 to the liquid line at the Jetty JL2. The offloading line JL2 is operative to fluidly connect and commingle LNG flow from any one or all floating storage structures. The liquid line or offloading line JL2 is operative to fluidly connect the commingled LNG flow to the LNG carrier through the external transfer system for offloading JL4. The external transfer system for offloading JL4 is operative to fluidly connect the offloading line JL2 to one or more cargo tanks of a LNG carrier .

In some embodiments, the internal transfer system for offloading L6 is provided at the jetty, e.g. installed at or fluidly connected to jetty offloading line JL2.

In some embodiments, the offloading line JL2 comprises of necessary piping, insulation, valves, instrumentation and controls to allow for the transfer of LNG from any one

internal transfer system for offloading L6 to another internal transfer system for offloading L6 to allow the transfer of LNG from any one floating storage structure to any other floating storage structure.

In some embodiments, the offloading line L2 comprises of necessary piping, insulation, valves, instrumentation and controls to allow for the transfer of LNG from any one or more storage tanks G3 to another one or more storage tanks of the same floating storage structure, or for the offloading of LNG from any one or more storage tanks to an internal transfer system for offloading L6. From the internal transfer system for offloading L6, LNG can be transferred to storage tanks of another floating storage structure through the jetty liquid line JL2.

In some embodiments, LNG cargo pumps L11 are provided and operative to move or transfer LNG out of storage tanks either for internal transfers to other storage tanks or offloading operations. LNG transfers between cargo tanks can be achieved by pumping LNG using the cargo pumps L11 from any storage tank through the offloading line L2 to the targeted storage tanks by simply opening isolating valves L13 located at the tank's filling line L12. Thus, LNG can be transferred to any one or more cargo tanks onboard on any of the floating storage structures and without affecting any ongoing loading operations.

Prior to starting offloading operation, an offloading plan is prepared to determine ramp up and ramp down rates, as well as a predetermine offloading storage tanks sequence. Once the LNG carrier G2 is ready to receive LNG and the offloading line L2 and JL2 and transfer systems L6 and JL4 are cold (see cooldown system), offloading operation commences during which LNG is pumped from the pre-determined (offloading) storage tanks G3 using their submerged pumps L11 and distributed through the offloading line L2 to the internal transfer system for offloading L6 which may be provided at the loading jetty, then from the internal transfer system for offloading L6 to the jetty liquid line JL2 and external transfer system for offloading JL4 and finally from the external transfer system for offloading JL4 to the LNG carrier G2. The floating storage structure may employ one or more external transfer system for offloading JL4 depending on the type of offloading transfer system being used, flow and redundancy requirements.

LNG flowing through the external transfer system (s) for offloading JL4 will be distributed or allocated into tanks of the LNG carrier G2 based on the tank arrangements of the LNG carrier and offloading plan.

LNG flow to the LNG carrier G2 can be controlled by increasing or reducing the pumps speed or number of pumps L11 in use and by throttling the valves located at discharges lines of each storage tank G3 that feed into the main offloading line L2.

At the end of offloading operation, cargo pumps L11 are stopped, valves closed, piping and transfer systems drained warm up and inert if necessary.

A vapour system F3 shown in Figure 8 is provided and operative to fluidly connect the onshore plant G7, one or more floating storage structures G1 and one or more LNG carriers G2 for managing vapour or boil-off gas pressure during simultaneous loading and offloading operations. More particularly, the LNG carrier G2 is operative to fluidly connect to the onshore plant G7 and further to one or more floating storage structures G1. More particularly, one or more carrier tanks of one or more LNG carriers G2 are operative to fluidly connect to the onshore plant G7 and further to one or more storage tanks G3 of one or more floating storage structures G1. Vapour system F3 ensures that the overall vapour pressure at the floating storage structure and storage tanks G3 remains stable and that all excess vapour generated onboard floating storage structures G1 and from receiving LNG carrier G2 during offloading operations is sent back to onshore plant G7 for processing.

Reference is made to Figure 4, 5 and 9. The vapour system (or third set of pipelines) include an emergency release to flare V8, set of pipelines at the jetty JL3, internal transfer system for vapour V5, a vapour control valve V3, vapour header line V1 or first vapour line, branch-off line V2 to each storage tank G3.

The vapour header line V1 is operative to fluidly connect one or more storage tanks G3 through a branch off-off line V2. The internal transfer system for vapour V5 is operative to fluidly connect the vapour header line V1 to the jetty vapour line JL3. The jetty vapour line JL3 is operative fluidly connect the internal transfer system for vapour V5 from each of the floating storage structures to the onshore plant G7. The vapour header line V1 is operative to collect vapour produced by the storage tanks V4 via the branch-off line V2 and direct the vapour back to the onshore plant G7 via and internal transfer system for vapour V5 and jetty vapour line JL3.

An emergency vapour release branch-off line V8 is provided to relieve pressure from the floating storage structures G1 and LNG carrier G2 to the onshore flare in order to protect storage tanks G3 and piping systems from over pressurization.

In some embodiments, another vapour control valve V7 is operative to fluidly connect the second vapour line JL3 to the floating storage structure(s) and distribute at least some of vapour flow into or stop all flow into the floating storage structure.

In some embodiments, a vapour control valve V3 is operative to fluidly connect the vapour header line V1 to the internal transfer system for vapour V5 and allow controlled transfer of some vapour returned from the LNG carrier G2 into the vapour header line V1 to compensate for the volume displaced by LNG pumped out of the storage tanks G3 during offloading and to maintain stable overall pressure and avoid tank over pressurization or vacuum.

During abnormal conditions, all the vapour can be redirected to a flare on shore.

In some embodiments, the vapour header line V1 comprises of necessary piping, insulation, valves, instrumentation and controls to allow collection of BOG or vapour produced by storage tank G3 of the floating storage structure G1 and direction of the collected vapour to a compressor room in which the collected vapour would be compressed for re-liquefaction, or re-directed for fuel or to flare for burning (not shown in figures).

In some embodiments, the compressor room may be located onshore, e.g. at LNG plant, or at the jetty for easier modularization. In some other embodiments, the compressor room may be located at the floating storage structure.

In some embodiments, the internal transfer system for vapour V5 may be located at the jetty.

During loading operation, where LNG is transferred from onshore plant G7 to floating storage structure G1, as the LNG enters a cargo tank G3, vapour (BOG) is generated by liquid flash, volume displacement and heat ingress. The vapour flows out of the cargo tank G3 through the branch off line V2 to the vapour header line V1, through pressure control valve V3 if any, through the internal transfer system for vapour V5 and through the jetty vapour line JL3 to shore. Additional BOG compressors on each floating storage structure or on the jetty are optional if the piping system cannot achieve free flow of vapour back to shore.

During offloading operation, where LNG is transferred from floating storage structure G1 to LNG carrier G2, a large amount of vapour is generated onboard the LNG carrier G2,

which normally peaks at the start when the carrier tanks are empty and relatively warm. Vapour produced at LNG carrier tanks is pushed back to the floating storage structure G1 by the carrier's BOG compressors through its mid-ship manifold vapour return line which is fluidly connected to the external transfer system for vapour JL5. Some of the vapour produced at carrier tanks is used to maintain stable pressure of the storage tanks G3 of the floating storage structures G1, this is achieved by vapour flowing into the floating storage structures through the jetty vapour piping JL3 and internal transfer system for vapour V5, vapour control valve V3 if any, vapour header line V1, branch-off lines V2 and eventually to the storage tanks G3. The excess vapour from LNG carrier continues its flow through the jetty vapour line JL3 to BOG compressors in the onshore plant G7. Shore BOG compressors ensure the overall BOG system pressure is maintained stable and any malfunction will cause the BOG to be re-directed to flare.

During inter-tank transfers, the vapour is equalized by the natural flow of vapour between cargo tanks G3 as they remain fluidly connected through a normally open vapour header line V1 and branch-off lines V2

In case vapour pressure in the system breaches pre-set safety limits, a release of vapour is performed or activated through an emergency vapour branch off line V8 into the flare. If above system fails to activate, additional pressure protection systems will release excess pressure through an onboard vapour release mast or each of the cargo tank's independent pressure/vacuum protection valves V11.

A cooldown system comprises of necessary piping, insulation, valves, instrumentation and controls to allow all required cooldown operations on pipelines, storage tanks, transfer systems as required by the overall floating storage structure and plant design requirements.

Reference is made to Figures 4, 6, 9 and 10. The cooldown system provides pre-cooling of storage tanks G3 prior to loading operation by pumping LNG from any of the tank's cooldown pump C9 to the targeted storage tank's spray system C10 via the cooldown (spray) header line C1.

The cooldown system also provides for pressure control in storage tanks G3 by cooling down the tank's vapour space by pumping LNG into the target tank's spray system C10.

The internal return transfer system for cooling C5 can provide cooling services to the LNG plant through the jetty cooldown line JC1.

A cooldown connection C8/S9 is provided to receive inert gas from the inert gas system (see Figure 7) for the purpose of decommissioning the cooldown system or maintenance operations.

A tie-in connection to loading and offloading system C6/L8 is provided to allow circulation of LNG to the offloading line Figure 3- L2, internal transfer system for offloading L6, jetty offloading line JL2 and external transfer system for offloading JL4 for pre-cooling prior to any storage tank G3 transfer or offloading operations. The LNG is circulated from any cargo tank using cooldown pumps C9.

Alternatively LNG for cooling can be supplied by the onshore plant G7 from the loading line JL1 and tie-in connection JL6

A cargo tank spray system C10 operates by pumping LNG using the existing cooldown pump C9 via the same tank's spray system C10 or send LNG to another tank spray system via the cooldown spray header C1. The main purpose of the cooldown system is for tank cooldown in preparation for loading and/or to control the tank's internal pressure by cooling its vapour space.

In preparation for offloading operation, the cooldown system can be used for the initial cooling down of the offloading lines. To cool down the liquid lines, LNG is pumped from a source tank using the cooldown pump C9 and directed to the offloading system F2 via the tie-in to liquid system connection C6/L8. Through the tie-in connection, LNG will flow through the entire offloading line L2, internal transfer system for offloading L6, jetty piping JL2 and external transfer system for offloading JL5 till the complete system reaches the appropriate temperature to allow safe offloading with cargo pumps L11. Depending on the floating storage structure's offloading frequency, the cooldown system can also provide a continuous recirculation to avoid the need of pre-cooling prior to every offloading operation.

An inert gas system is provided to the floating storage structure G1. The inert gas system provides inert gas and dry air respectively in connection with isolation, decommissioning, inspection and recommissioning of one or more tanks G3 while maintaining the remaining tanks G3 in operation. It is also used for inert spaces exposed to

NG ingress in case of storage tank leakage or even for corrosion prevention of empty unused spaces (void space) S5.

Type of inert gas used depends to specific requirements, cost of equipment and availability of outside sources. Current application considers the use of nitrogen or low oxygen air as possible inert gas supplied from the onshore plant G7.

A dry air supply equipment can be installed on board or can be supplied from shore and the inert gas/air heater is optional to allow for faster operations.

In some embodiments, the inert gas system is provided at the jetty 4.

Reference is made to Figure 3, 7 and 10. An inert gas header S1 having branch-off lines to allow supply of inert gas or dry air into cargo holds or void spaces S5, depending on the type of cargo tank containment system used, is provided.

A service line header S2 having branch off lines leading to storage tanks G3 is provided to allow the selective connection to storage tanks G3 for decommissioning, tank entry and subsequent recommissioning, while other storage tanks G3 remain in operation.

An inert gas is provided from shore through internal transfer system for service S10 which is operative to fluidly connect the jetty service line JS1 to inert gas line S1 and service header S2 to provide inert gas or dry air for all operations when as needed.

An inert gas and/or air heater S7 is provided with optional fluid connections to the service header S2 or/and inert gas header S1 to be used to supply hot inert gas or hot dry air for the purpose of storage tanks and pipeline warm up as and when needed. Optionally, a single heater can be used for either inert gas or NG heating.

A tie-in connection to the offloading system S8/L7 is provided to allow the supply of inert gas to the offloading line L2, internal transfer systems for offloading L6 and jetty offloading line JL2 when as needed.

During normal operations, the inert gas system supplies dry air or inert gas to void spaces adjacent to storage tanks through the jetty service line JS1, internal transfer system for service S10 into the inert gas header S1 and distributes it to void spaces S5 (cargo holds) via branch-off lines.

For the purposes of decommissioning and recommissioning of storage tanks G3, as required for maintenance, regulatory inspections, last minute repairs, etc., the inert gas system will support the process of decommissioning, ventilation and recommissioning of any one or more tanks.

During decommissioning of tanks, the targeted storage tanks G3 are isolated from the liquid loading and offloading systems and a temporary connection is fitted to fluidly connect the service line header S2 branch off line to the filling line L12 between the tank penetration and the first valve. Then, a shore inert gas generator supplies dry clean inert gas directly to the tanks by flowing through jetty service line JS1, internal transfer system for service S10 and service line header S2 and purging NG out of the targeted storage tanks G3. Alternatively provides warm inert gas by flowing through the heater S7 (Optional) before distributing it with the same service header to the targeted cargo tanks.

After all the NG has been purged out of the cargo tank, shore supply switches from inert gas to dry air to purge the inert gas out of the tank and make the space safe for entry. During storage tank man entry, the service line header S2 supplies ventilation air continuously to ensure a safe environment for personnel at all times.

During recommissioning of tanks for return to service, the shore supply switches back from dry air to dry inert gas which flows to the target storage tanks G3 through the service header S2 and branch off lines to replace the air in the tanks with inert gas in preparation for gas-up and cooldown.

Once all the tank is inert, NGs for gas-up can be supplied from other tanks through the existing vapour header line V1 and branch off lines V2 by re-opening vapour isolating valves of the target storage tanks G3.

Alternatively, the cooldown system can provide NG vapour to the targeted storage tanks G3 for gas-up through the tie-in to cooldown system connection S9/C8 to the service header S2 and branch-off connections.

Final cooldown of the tanks is done by the cooldown system by pumping LNG from any of the other tank's cooldown pump C9 to the targeted storage tank's spray system C10 via the cooldown (spray) header line C1 until the tank reaches a temperature suitable for the reintroduction on LNG.

If decommissioning and recommissioning of the loading and/or offloading system is required, the inert gas system can provide inert gas or dry air respectively directly to the loading and/or offloading system through the tie-in to liquid system connection S8/L7.

An automation and control system (including safety systems) is provided to allow the monitoring and control of all cargo related operations from a single control room which is located at onshore plant G7.

Power, utility and control lines as shown in Figure 10 are provided and extend from onshore power, utility and control facilities at the onshore plant G7 to the floating storage structures G1 for operation thereof through JU1. It is to be appreciated that separate lines can be provided for power supply, utility and control signals.

Reference made to Figure 8. A method of operating the LNG export terminal 1 is described here. Generally, for operation as a LNG export terminal 1, LNG is transferred from the onshore plant G7 to one or more floating storage structures G1 and, subsequently, from the floating storage structures G1 to one or more LNG carriers G2 berthed at the jetty 4 to be transported to another location.

At the onshore LNG plant G7, natural gas (NG) is processed and liquefied into LNG. The LNG is supplied through the liquid loading system F1 to the designated floating storage structure (s) G1. It is to be appreciated that the LNG may be stored at an onshore tank of the onshore LNG plant G7 before being supplied through the liquid loading system F1 to the designated floating storage structure(s) G1. The LNG supplied through the liquid loading system F1 is then stored at the floating storage structure(s) G1 storage tanks G3.

At the onshore plant G7, power generation, utility and control facilities, electrical power, utilities and control signals are produced and are supplied through respective lines Figure 10 –JU1, e.g. power cables, utility lines, electrical signal lines, to the designated floating storage structure G1 for operation thereof. It is to be appreciated that the electrical power and/or utilities may be stored onshore before being supplied through respective lines to the designated floating storage structure G1.

BOG generated on the floating storage structures G1 is collected by the vapour system F3 and returned back to onshore plant G7 for re-processing. The proper collection and management of the BOG is important to control the pressure in the storage tanks G3 and ensure the stability of the LNG terminal 1 and onshore plant G7 liquefaction process.

A LNG carrier G2 for exporting the LNG to another location is berthed at the loading jetty portion 7. Using the offloading system F2 which receives LNG from the floating storage structures G1, LNG stored at the floating storage structure tanks G3 is offloaded to the LNG carrier G2.

When offloading to the LNG carrier G2, vapour or BOG generated by the carrier is collected by the vapour system F2. A portion of the collected vapour is returned back to the storage tanks G3 of the floating storage structures G1 to compensate for the volume of LNG which was transferred from the storage tanks G3 of the floating storage structures G1 to the LNG carrier G2 and the remaining vapour is sent back to shore plant G7 for re-processing. The vapour system F3 ensures that BOG pressures between the carrier G2 and the floating storage structures G1 is equalized and ensure the stability of the system.

For inventory management as and when required, LNG is transferred from one floating storage structure G1 to another floating storage structure G1 through the liquid offloading system F2.

Operation reliability and continuity failures in the floating storage structures might lead to a reduction on the floating storage structure capabilities but shall not lead to shutdown of the onshore plant G7. If one floating storage structure G1 or any storage tank G3 within the floating storage structure G1 is out-of-service, storage of LNG can be transferred to another floating storage structure G1 or another storage tank while the affected floating storage structure G1 or storage tanks G3 is being repaired or replaced. For example, in an extreme case, a completely out-of-service floating storage structure G1 can be decoupled from the permanent mooring system G8 and transported away from the LNG terminal 1 and, subsequently, a replacement floating storage structure is installed in place of the out-of-service floating storage structure G1, and in the meantime, the LNG terminal can operate with the remaining floating storage structure G1. Alternatively, if any storage tanks G3 within the floating storage structure G1 is out-of-service and the remaining tank(s) G3 remain operational, the floating storage structure G1 may not require replacement.

For operation productivity and safety, the floating storage structures G1 are controlled as an integral part of the onshore plant G7. Since electrical power and utilities are transferred from an onshore plant G7 to the floating storage structures G1 no personnel is needed onboard the floating storage structures G1 during normal operations. Therefore, the LNG terminal can be operated as a fully integrated part of the onshore LNG plant, in a similar manner as conventional land-based tanks.

It is to be appreciated that the LNG terminal 1 arrangement according to the invention may alternatively be used as a LNG import terminal. Generally, for operation as a LNG import terminal, LNG is transferred from a LNG carrier G2 berthed at the loading jetty portion 7 to the floating storage structures G1 and, subsequently, from the floating storage structure G1 to an onshore LNG plant G7 where the LNG is stored and or re-gasified before distributing to the consumers, e.g. industries and retail users, by pipelines, rail, land vehicles or water vessels. Accordingly, the onshore LNG plant G7 would include a re-gasification facility. Alternatively LNG can be reloaded to smaller vessels, rail tanks or truck tanks for further distribution.

Suitable modifications to the pipelines would be required including, but not limited to, modifying floating storage structure tank offloading lines to fluidly connect to the first set of pipelines instead of to the second set of pipeline in order to transfer LNG to the onshore LNG plant. In other words, the liquid loading system (F1) or first set of pipelines would be employed for liquid offloading while the liquid offloading system (F2) or second set of pipelines would be employed for liquid loading.

The invention is herein described in non-limiting embodiments and variations. A person skilled in the art will understand that there may be made alterations and modifications to the embodiments and variations that are within the scope of the invention as described in the attached claims.

CLAIMS

1. An LNG terminal (1) for steep water shorelines, the terminal comprising:
 - an onshore LNG facility (G7),
 - at least one floating storage structure (G1), the at least one floating storage structure (G1) comprising an elongated shape with a first end (2) and a second end (3),
 - a permanent mooring system (G8) for mooring the at least one floating storage structure (G1),
 - a jetty (4), the jetty (4) extending in a longitudinal direction from a shoreline (5) out into a body of water (6) and terminating at a loading jetty portion (7), the loading jetty portion (7) comprising a first mooring arrangement (8) for mooring an LNG carrier (G2) and an external transfer system (G6),
 - the jetty (4) further comprising at least one internal transfer system (G5), the at least one internal transfer system (G5) being arranged at a point along the length of the jetty between the shoreline (5) and the loading jetty portion (7),
 - a pipeline system (9) adapted for transporting hydrocarbons between the onshore LNG facility (G7), the at least one internal transfer system (G5) and the external transfer system (G6),

wherein the floating storage structure (G1) is connected to the internal transfer system (G5) at the first end (2) of the floating storage structure (G1),

wherein the internal transfer system (G5) includes flexible pipes and/or articulated connections and is provided for transfer of fluid between the jetty (4) and the floating storage structure (G1), that are subject to relative motion therebetween,

and where the floating storage structure (G1) is moored such that the second end (3) is oriented in an angle substantially perpendicular to the longitudinal direction of the jetty (4),

wherein the at least one floating storage structure (G1) comprises a second mooring arrangement (10) for mooring the LNG carrier (G2) to the floating storage structure (G1).
2. The LNG terminal (1) according to any of the preceding claims, wherein the pipeline system (9) comprises a loading system (L1, F1) extending between the onshore LNG facility (G7) and the at least one internal transfer system (G5).
3. The LNG terminal (1) according to any of the preceding claims, wherein the pipeline system (9) comprises an offloading system (L2, F2) extending between the at least one internal transfer system (G5) and the at least one external transfer system (G6).
4. The LNG terminal (1) according to any of the preceding claims, wherein the pipeline system (9) comprises a vapor system (V1, F3) extending between the onshore LNG facility (G7), the at least one internal transfer system (G5) and the external transfer system (G6).

5. The LNG terminal (1) according to any of the preceding claims, wherein the jetty (4) comprises at least two internal transfer systems (G5), the at least two internal transfer systems (G5) being arranged on opposite sides of the jetty (4) in the jetty's longitudinal direction.
6. The LNG terminal (1) according to claim 5, wherein the terminal (1) comprises at least two floating storage structures (G1), wherein each internal transfer system (G5) is connected to a separate floating storage structure (G1).
7. The LNG terminal (1) according to any of the preceding claims, wherein the terminal (1) comprises at least two floating storage structures (G1), wherein at least one first floating storage structure (G1) is connected to an internal transfer system (G5) at a first end (2) of the floating storage structure (G1), and a second floating storage structure (G1) is connected to the second end (3) of the first floating storage structure (G1).
8. The LNG terminal (1) according to claim 6, wherein the at least one second floating storage structure (G1) is moored in a substantially similar longitudinal direction as the first floating storage structure (G1).
9. The LNG terminal (1) according to any of claims 6 or 7, wherein the at least one second floating storage structure (G1) is connected to the pipeline system (10) via the first floating structure (G1).
10. The LNG terminal (1) according to any of the preceding claims, wherein the onshore LNG facility (G7) comprises facilities for boil-off gas collection and management.
11. The LNG terminal (1) according to any of the preceding claims, wherein the onshore LNG facility (G7) comprises facilities for controlling the terminal.
12. The LNG terminal (1) according to any of the preceding claims, wherein the onshore LNG facility (G7) comprises facilities for electric power generation, power storage facility and/or power transmission.
13. The LNG terminal (1) according to any of the preceding claims, wherein the onshore LNG facility (G7) comprises facilities for producing, processing and/or storing utilities, wherein utilities comprise any of: nitrogen, water, cooling water, compressed air, instrument air, heating and drainage collection

14. The LNG terminal (1) according to any of the preceding claims, wherein the jetty (4) comprises means for transferring between the onshore LNG facility (G7) to the at least one floating storage structure (G1), any of: electric power, control signals and utilities.
15. The LNG terminal (1) according to any of the preceding claims, wherein the at least one floating storage structure (G1) comprises a plurality of storage containers (G3).
16. The LNG terminal (1) according to claim 14, wherein the at least one floating storage structure (G1) comprises a cargo management system arranged to load and offload LNG from selected storage containers (G3).
17. The LNG terminal (1) according to any of claim 15, wherein the at least one floating storage structure (G1) comprises an inert gas system arranged to provide inert gas and dry air to selected storage containers (G3).