A floating independent power plant and method of converting an LNG carrier into one

Field of the invention

[001] The present invention relates to a floating independent power plant (FIPP) comprising a converted LNG carrier with a hull and a plurality of LNG storage tanks. The invention further relates to converting an LNG carrier into a floating independent power plant and to a power generator module for conversion of an LNG carrier into a floating independent power plant.

Background art

[002] A method of converting a LNG carrier into a floating LNG plant is known from WO 2012/072292. Herein, the LNG carrier comprises as least a hull and a plurality of LNG storage tanks and the floating LNG plant comprises at least one sponson on the side of the hull, for creating additional hull volume, process equipment for LNG processing on the floating LNG plant, and a reservoir for storing fluids separated during the LNG processing, wherein said reservoir is formed by the ballast tank or in the space reserved for the ballast tank of the original LNG carrier. By using an existing tanker, project risk is reduced because the vessel is already available and not on the critical path for project schedules. The floating LNG plant, however, is limited to use with natural gas distribution systems for supplying natural gas to users onshore.

[003] The present invention seeks to provide a floating LNG plant for supplying power. The present invention further seeks to provide a floating LNG plant which can be manufactured by converting an LNG carrier with reduced production in critical time. Further, the present invention seeks to provide a floating solution which allows to keep the initial full containment system of an LNG carrier.

Summary of the invention

[004] Hereto, according to a first aspect, the present invention provides a floating independent power plant (FIPP) comprising a converted LNG carrier with a hull and a plurality of LNG storage tanks arranged within the hull, wherein the floating independent power plant comprises: a regasification unit, connected with an inlet to the plurality of LNG storage tanks, for regasification of stored LNG; a sponson on either side of the hull, each sponson being subdivided into a plurality of substantially equally sized compartments along the length of the sponson; a plurality of power generator modules comprising power generator sets, each forming one of the plurality of compartments and provided with an inlet connected to an outlet of the regasification unit for receiving fuel gas and adapted for generating electricity using the received fuel gas, wherein each of the compartments comprising a power generator set is provided with an exhaust stack and an air inlet in an upper side, with the exhaust stack and air inlet being located on longitudinally opposite sides of the compartment and with the exhaust stacks of adjoining compartments being combined; and cooling equipment, coupled to the plurality of power generation modules and arranged to cool the plurality of power generation modules.

[005] The FIPP may be moored at any location where power needs be supplied. The lay-out of the FIPP allows the compartments of the sponsons holding the power generator sets being manufactured as modular units, which can be nearly finished prior to integration into the sponson. As a result, manufacturing logistics and efficiency are Improved. By placing the adjoining modular units in mirror

position around adjoining walls, the exhaust stacks of adjoining compartments are combined, saving deck space.

[006] Furthermore, with the power generation modules being located in the sponsons, which are added to the outside of the hull, the electricity producing elements are added onto and integrated with existing systems of the LNG carrier, thus refurbishment steps of the original LNG carrier parts is limited.

[007] In the present text, the phrase “LNG carrier” or "original LNG carrier" is used. This means a vessel that has originally been constructed for transporting LNG.

[008] In the present text the word “sponson” is used. The word sponson refers to any projecting hull structure in order to provide additional hull volume. The sponson normally extends along the length of a vessel. Optionally, the top side of the sponson can be made flat, thereby providing additional deck space. The top side could be adapted to be flush with the vessel’s main deck. However, it should be noted that the top side of a sponson does not need to be flat and does not need to be flush with the vessel’s main deck. It is very well possible to connect a sponson to the hull below the main deck.

[009] According to an embodiment, the sponson Is divided in a lower part and an upper part. The lower part serves as a base onto which the power generator modules are placed to form the upper part and is integrated to the original LNG carrier in a dry-dock. This allows the generator modules being integrated with the vessel afloat, reducing the amount of time the vessel needs to be in the dry-dock. Furthermore, the power generator modules forming the upper part of the sponson may be assembled and pre-commissioned prior to integration on the lower sponson parts. Thus many construction phases of the FFIP may be carried out in parallel, reducing critical time of construction phases carried out on the vessel.

[0010] According to an embodiment. the FIPP comprises at least ten power generator modules and each sponson is subdivided into at least five compartments. Each power generator module may produce 18MW power, allowing the FIPP to produce at least 180MW in total.

[0011] In an embodiment, the floating independent power plant comprises a steam turbine generator and/or one or more diesel generators for supporting sailing such that the floating independent power plant is self-propelled during deployment. Having a propulsion unit on-board advantageously allows the vessel being repositioned and deployed to different locations without need of additional support vessels for towing.

[0012] In an embodiment, the cooling equipment comprises a closed fresh water circulation loop for each power generator set and a heat exchanger installed above each of the sponsons and/or on the main deck in direct contact with the outside environment, with each of the closed fresh water circulation loops running between one of the power generation sets and the heat exchanger, the heat exchanger being an air flow heat exchanger. As a result, no use is made of seawater for cooling the power generator sets. Thus no heated seawater is being returned to the sea, making the vessel compliant with the most severe environmental requirements on this subject.

[0013] In an embodiment, the air flow heat exchanger comprises a plurality of air cooled cells. This creates a large heat exchange area.

[0014] In an embodiment, the air flow heat exchanger further comprises at least one fan for providing forced airflow as local cooling medium, providing enhanced heat transfer.

[0015] In an embodiment, each power generator set is provided with at least one dedicated air cooled cell, such that each power generator set has dedicated cooling. This set-up avoids the need of a very large collector and a general pumping system for distributing cooling water evenly over each of the power generation modules when in use. The use of dedicated systems allows individual operation of each of the power generation modules according to match the electricity needs, i.e. when a relatively low amount of electricity is required from the FIPP some power generation modules may be switched off. Each unit operates as a separate entity.

[0016] In an embodiment, the cooling equipment comprises a closed fresh water circulation loop for each power generator set and a heat exchanger installed in the hull or one of the sponsons, with each of the closed fresh water loops running between one of the power generator sets and the heat exchanger for exchanging heat therewith and wherein the heat exchanger is connected with an inlet to at least one cold seawater storage tank for receiving seawater as cooling medium in the heat exchanger and with an outlet extending through the hull to overboard heated seawater to open sea, wherein the cold seawater storage tank is located in one or more compartments of the sponsons not holding a power generator set and the cold seawater storage tank is provided with a connection to a seawater lift system. The sea water lift system is already commonly available vessels for cooling on-board. This system does not require additional deck space, unlike the air cooling.

[0017] In an embodiment, each of the closed fresh water circulation loops comprises a pump for pumping the fresh water through the closed fresh water circulation loop, which pump is driven by the power generator set. This allows each unit being operated as a separate entity.

[0018] In an embodiment, the regasification unit is provided with a closed fresh water circulation loop which runs between the regasification unit and the heat exchanger, for cooling the regasification unit.

[0019] In an embodiment, the floating independent power plant comprises an export gantry for connecting to an onshore grid for supply of the generated electricity thereto.

[0020] According to a second aspect, the invention provides a method of converting a Moss type LNG carrier to a floating independent power plant, comprising the steps of removing existing bilge keels from either side of the hull; providing a plurality of power generator modules each comprising a power generator set, an air inlet and an outlet, wherein the air inlet and the outlet are located on opposite sides of the module; assembling the plurality of power generator modules in an upper part of two sponsons, such that each of the two sponsons is subdivided into a plurality of substantially equally sized compartments along a longitudinal direction, and such that adjoining power generating modules are mirrored around their adjoining wall, and combining the outlets of adjoining power generator modules in a funnel of exhaust pipes; attaching the two sponsons to either side of the hull, integrating a lower part of each sponson at the location of the bilge keel; providing a regasification unit for creating fuel gas from LNG, connecting said regasification unit with an inlet to the LNG tanks and with an outlet for supplying created fuel gas to the plurality of power generator modules.

[0021] In an embodiment, the method further comprises providing each of the power generator modules with at least one air cooled cell on an upper side forming a deck of the sponson and a closed fresh water circulation loop running between the power generator set and said at least one air cooled cell. Preferably, this step is carried out for each sponson after the assembly of the plurality of power generator modules therein. However, optionally the air cooling system may be included in each modules prior to integration into the sponsons.

[0022] In an embodiment, the method further comprises providing at least one fan on an upper side of each of the power generator modules for creating a forced airflow that is directed over the at least one air cooled cell.

[0023] According to a third aspect, the in invention provides a sponson for converting a Moss type LNG carrier to a floating independent power plant according to the method of claim 11, the sponson being subdivided into a plurality of substantially equally sized compartments along a longitudinal direction of the sponson and arranged to receive a plurality of power generator modules, each holding one power generator module, arranged such that adjoining power generating modules are mirrored around their adjoining wall, the sponson comprising at least one funnel of exhaust pipes for combining the outlets of adjoining power generator modules and said sponson being adapted for being fixedly mounted on a side of the hull of the Moss type LNG carrier.

Brief description of the drawings

[0024] Embodiments of a floating independent power plant according to the present invention will be described by way of example, with reference to the attached drawings, in which:

[0025] Fig. 1 shows a high-level schematic of the power generating system of a floating independent power plant;

[0026] Fig. 2A shows a schematic top view of an embodiment of a floating independent power plant according to the invention;

[0027] Fig. 2B shows a schematic cross-section of the floating independent power plant of Fig. 2A;

[0028] Fig. 2C shows a schematic of the cooling system of the floating independent power plant of Figs. 2A and B;

[0029] Fig. 3A shows a schematic top view of an embodiment of a floating independent power plant according to the invention;

[0030] Fig. 3B shows a schematic cross-section of the floating independent power plant of Fig. 3A; and

[0031] Fig. 3C shows a schematic of the cooling system of the floating independent power plant of Figs. 3A and B.

Description of embodiments

[0032] Fig. 1 shows a high-level schematic of the power generating system of a floating independent power plant (FIPP). The FIPP is shown to comprise manifolds 31, LNG tanks 30, a regasification unit 40, a boiler 41, a propulsion unit 42, a power generation module 50 with a power generator set 51 and a cooling system 52, and an export gantry 59. The manifolds 31 serve as an inlet to the LNG tanks 30 and are adapted for loading LNG via marine loading hoses from LNG carriers which more alongside the FIPP. The regasification unit 40 is with an inlet connected to an outlet of the LNG tanks 30 and is adapted to regasify LNG to provide

gas as fuel gas via a first outlet to the plurality of power generation sets 51 and via a second outlet to the boiler 41. The boiler 41 is with a first outlet connected to the propulsion unit 42 and with a second outlet connected to the plurality of power generation sets 51. The power generation sets 51 are each connected with an electric output to the export gantry 59 for exporting generated electricity to a power grid. Each of the power generation sets 51 is individually connected to a cooling system 52. Two embodiments of FIPP cooling systems are described in more detail with reference to Figs. 2C and 3C.

[0033] The regasification unit comprises at least one centrifugal type fuel gas compressor (not shown) to compress boil-off gas from the LNG tanks 30 to a required fuel gas pressure for the gas engines. The at least one fuel gas compressor discharges pressurised gas to at least one fuel gas after-cooler/heater (not shown), which regulates the final temperature of the fuel gas prior to feeding the gas engines. The regasification unit further comprises at least one steam heated fuel gas vaporiser (not shown), adapted to produce from the LNG additional fuel gas which is required on top of the boil-off gas and suitable for direct supply to the gas engines. Pressurised LNG is introduced from the LNG tanks 30 and the boil-off gas is combined with the fuel gas downstream of the after-cooler/heater. The amount of boil-off gas and additional fuel gas in the mixture varies between 0% and 34%, depending on the operation and level of LNG in the LNG tanks. During loading and when the LNG tanks are full, a maximum of boil-off gas is generated such that the mixture contains 34%. As the level of LNG in the LNG tanks decreases, the amount of boil-off gas in the mixture decreases (linearly) to 0%. Each power generator set 51 comprises at least one gas engine and an electric power generator (both not shown), wherein the gas engine(s) will deliver mechanical power to the electric power generator(s) for the production of electricity.

[0034] When the FIPP is in power production mode, the gas at fuel gas power is lead from the regasification unit to at least one of the plurality of power generation modules 50 into the power generator set 51 thereof. According to an embodiment, the generated electricity from the at least one power generator set 51 is generated at 15 kV and raised up to 132 kV export voltage, metered and subsequently supplied to the on-shore grid through the export gantry 59. The export voltage can be set to specific project needs. During this operation, the boiler 41 is running in order to supply steam for local power generation and LNG vaporisation. A boil-off gas system which is already present in the original LNG carrier is used for supplying gas to the boiler 41.

[0035] During deployment, the FIPP is self-propelled with a high pressure steam system as propulsion unit. The boiler 41 burns marine gas oil and/or gas depending on the LNG storage on board. All power generator units are shut-down during sailing. The required electricity for supporting the FIPP sailing is generated by a steam turbo generator and/or diesel generator, which is already present in the original LNG carrier from which the FIPP is converted and which is part of the aforementioned propulsion unit 42. Where a steam turbo generator is used, a secondary function of the boiler comprises continuous LNG gas burning, so that no diesel oil consumption is required.

[0036] Figs. 2A and 2B respectively show a schematic top view and cross-sectional view of an embodiment of a FIPP, with a detailed schematic of the cooling system thereof shown in Fig. 2C. The FIPP is a vessel, with four Moss type LNG tanks 30, having a sponson 10, 20 on both sides of the hull 1. The sponsons 10, 20 extend over the full length of a cargo section of the hull 1 and are constructed to house the power generation modules 50 with the gas engine driven power generator sets 51 and their supporting systems. The sponsons

10, 20 are both subdivided into six equal length sections forming twelve compartments in total. In each of the compartments of one of the sponsons 20 a single power generator set 51 is installed. The compartments with the power generator sets 51 can be manufactured and pre-commissioned separately as power generation modules 50 and installed into the sponsons in a near-complete state. Four of the compartments of the other of the sponsons are each formed by a single power generation module 50, while the two compartments in the middle of the ship under the LNG transfer station have a seawater cooling system 60 installed.

[0037] Air inlets 54 and outlets are created in the upper side of each of the power generation module 50 compartments. These inlets 54 and outlets are located as far apart as possible on opposite sides of each compartment to maximise air flow there through. The outlets of two neighbouring compartments are combined into a single exhaust funnel 55 to minimise the number of structures on the upper deck of the sponsons 10, 20.

[0038] Preferably, the structures of the sponsons 10, 20 have the same frame distances as the original LNG carrier's hull 1 in order to guarantee continuation of the original LNG carrier's hull structure inside the sponsons for optimal load transfer in the structure. The lower part of each of the sponsons 10, 20 is integrated at the location of the former bilge keel at mid-ship. The height of the sponsons 10, 20 is continuous between the fore and aft ends, such that the upper sides of both sponsons 10, 20 is aligned with the upper deck of the hull 1. The shape of the hull 1 towards the ends thereof dictates a widening of the sponsons 10, 20 to maintain a proper connection between said sponsons 10, 20 and the hull 1. The sponsons 10, 20 are slightly tapered on both ends thereof to reduce the drag during sailing.

[0039] As visible in Fig. 2B, a pipe rack 58 is created on the upper deck to transport fuel gas, cooling water and cabling across the vessel. The pipe rack 58 is installed on the longitudinal sides of the deck of the original LNG carrier.

[0040] As shown in Fig. 2C, the cooling system 52' in this embodiment is based on a seawater cooling system 60. The cooling system 52' comprises a dedicated fresh water circulation loop 68 for each of the power generation modules 50 and the regasification unit 40, comprising at least one pump 51c for circulating the fresh water therein, and the seawater cooling system 60 located in the sponson 10, which comprises a sea chest 61, seawater lift pumps 62 and heat exchanger tanks 65. Each of the fresh water circulation loops 68 runs between the power generation module 50 or regasification unit 40, where the fresh water absorbs heat from the engines and auxiliaries, to the heat exchanger tanks, where the fresh water releases heat to the seawater therein, prior to being cycled back to the power generation module 50 or regasification unit 40. The sea chest 61 is located in the bottom of the sponson 10, below sea-level, and adapted to take in and store cold seawater. The seawater lift pumps 62 take 'cold' seawater as cooling medium from the sea chest 61 and pump it via inlets 63 into the heat exchanger tanks 65, where the cold seawater exchanges heat with the fresh water from the fresh water circulation loops 68 running there through. Heated seawater is expelled overboard the vessel via outlet channels 64, positioned at an upper side of the heat exchanger tanks 65.

[0041] Figs. 3A and 3B respectively show a schematic top view and cross-sectional view of an alternative embodiment of a FIPP, with a detailed schematic of the cooling system thereof shown in Fig. 3C. The embodiment of Fig. 3A-3C is similar to the one shown in Fig. 2A-2C, except that in the embodiment of Fig. 3A-3C both sponsons 10', 20' are subdivided into five equal length sections forming compartments, which have a single power generator set 51 installed therein. Furthermore, this embodiment's cooling system 52''

is an air cooling system, as shown in Fig. 3C. The air cooling system 52" comprises a dedicated fresh water circulation loop 68' for each of the power generation modules 50', comprising a pump 51c for circulation of the fresh water therein, and a heat exchanger 69' in the form of air cooler cells 65' provided with fans 67 creating a forced ambient air flow. The fresh water in the fresh water circulation loop 68' is heated up by the gas engine and auxiliary equipment in the power generation module 50' and pumped to the air cooling cells, which are located outside the compartment on or above deck level, to exchange heat with the ambient air flow prior to being cycled back to the power generation module 50'. The air cooling cells are for example arranged at deck level, which may extend over the sponsons, or alternatively on a higher level, for example mounted on a rack above deck level. Each power generation module 50' is connected via the dedicated fresh water circulation loop 68' to a dedicated heat exchanger 69', which is installed above the sponson 10', 20'. The dedicated heat exchanger 69' may take almost full width of the sponson, in some embodiments. In a preferred configuration, each heat exchanger has five air cooler cells 65'. The fresh water is preferably lead over or through the air cooler cells in a thin flow layer, for example through the use of a finned tube bundle, in order to create a large heat exchange area and enhance heat transfer. The fans 67 provide additional (forced) airflow over the surface of the air cooler cells 65', further enhancing heat transfer and thus improving the cooling capacity of the cooling system.

[0042] The air cooling system 52" is shown to replace the seawater cooling system of Fig. 2, but alternatively it may be desirable to use the cooling system of Fig. 3C in addition to the seawater based cooling system of Fig. 2C.

[0043] The present invention has been described above with reference to a number of exemplary embodiments as shown in the drawings. Modifications and alternative implementations of some parts or elements are possible, and are included in the scope of protection as defined in the appended claims.

Claims

1. A floating independent power plant, FIPP, (100; 200) comprising a converted LNG carrier with a hull (1) and a plurality of LNG storage tanks (30) arranged within the hull, wherein the floating independent power plant comprises:

- a regasification unit (40), connected with an inlet to the plurality of LNG storage tanks (30), for regasification of stored LNG;
- a sponson (10. 20; 10', 20') on either side of the hull (1), each sponson (10, 20; 10'; 20') being subdivided into a plurality of substantially equally sized compartments (50, 60; 50') along the length of the sponson (10,20; 10', 20');
- a plurality of power generator modules (50; 50') comprising power generator sets (51), each forming one of the plurality of compartments (50, 60; 50') and provided with an inlet connected to an outlet of the regasification unit (40) for receiving fuel gas and adapted for generating electricity using the received fuel gas, wherein each of the compartments comprising a power generator set (51) is provided with an exhaust stack (55) and an air inlet (54) in an upper side, with the exhaust stack (55) and air inlet (54) being located on longitudinally opposite sides of the compartment and with the exhaust stacks (55) of adjoining compartments being combined; and
- cooling equipment (52; 52'; 52"), coupled to the plurality of power generation modules (50; 50') and arranged to cool the plurality of power generation modules.

2. The floating independent power plant (100; 200) according to claim 1, comprising at least ten power generator modules (50; 50') and wherein each sponson (10, 20; 10', 20') is subdivided into at least five compartments along the length of the sponson (10, 20; 10', 20').

3. The floating independent power plant (100; 200) according to any one of the preceding claims, wherein the floating independent power plant comprises a steam turbine generator and/or one or more diesel generators for supporting sailing such that the floating independent power plant is self-propelled during deployment.

4. The floating independent power plant (200) according to any one of the preceding claims, wherein the cooling equipment (52") comprises a closed fresh water circulation loop (68') for each power generator set (51) and a heat exchanger (69') installed above each of the sponsons (10', 20') and/or on the main deck in direct contact with the outside environment, with each of the closed fresh water circulation loops running between one of the power generation sets and the heat exchanger, the heat exchanger being an air flow heat exchanger.

5. The floating independent power plant (200) according to claim 4, wherein the air flow heat exchanger (69') comprises a plurality of air cooled cells (65').

6. The floating independent power plant (200) according to claim 5, wherein the air flow heat exchanger (69') further comprises at least one fan (67) for providing forced airflow as local cooling medium.

7. The floating independent power plant (200) according to claim 5 or 6, wherein each power generator set (51) is provided with at least one dedicated air cooled cell (65').

8. The floating independent power plant (100) according to any one of claims 1 to 3, wherein the cooling equipment (52') comprises a closed fresh water circulation loop (68) for each power generator set 51) and a heat exchanger (65) installed in the hull (1) or one of the sponsons (10;20), with each of the closed fresh water loops (68) running between one of the power generator sets (51) and the heat exchanger for exchanging heat therewith and wherein the heat exchanger (65) is connected with an inlet (61) to at least one cold seawater storage tank (61) for receiving seawater as cooling medium in the heat exchanger and with an outlet (64) extending through the hull (1) to overboard heated seawater to open sea, wherein the cold seawater storage tank (61) is located in one or more compartments (60) of the sponsons (10, 20) not holding a power generator set and the cold seawater storage tank is provided with a connection to a seawater lift system (62).

9. The floating independent power plant (100; 200) according to any one of claims 4 – 8, wherein each of the closed fresh water circulation loops (68, 68') comprises a pump (51c) for pumping the fresh water through the closed fresh water circulation loop, which pump is driven by the power generator set (51).

10. The floating independent power plant (100; 200) according to any one of claims 4 – 9, wherein the regasification unit (40) is provided with a closed fresh water circulation loop which runs between the regasification unit and the heat exchanger.

11. The floating independent power plant (100; 200) according to any one of the preceding claims, wherein the floating independent power plant comprises an export gantry (59) for connecting to an onshore grid for supply of the generated electricity thereto.

12. A method of converting a Moss type LNG carrier to a floating independent power plant (100; 200), comprising the steps of

removing existing bilge keels from either side of the hull (1);

providing a plurality of power generator modules (50; 50') each comprising a power generator set (51), an air inlet (54) and an outlet (55), wherein the air inlet and the outlet are located on opposite sides of the module (50; 50');

attaching the two sponsons (10,20; 10', 20') to either side of the hull (1), integrating a lower part of each sponson at the location of the bilge keel;

assembling the plurality of power generator modules (50; 50') in an upper part of two sponsons (10, 20; 10', 20'), such that each of the two sponsons is subdivided into a plurality of substantially equally sized compartments (50, 60; 50') along a longitudinal direction, and such that adjoining power generating modules (50; 50') are mirrored around their adjoining wall, and combining the outlets (55) of adjoining power generator modules in a funnel of exhaust pipes;

providing a regasification unit (40) for creating fuel gas from LNG, connecting said regasification unit with an inlet to the LNG tanks and with an outlet for supplying created fuel gas to the plurality of power generator modules (50; 50').

13. The method according to claim 12, further comprising

providing each of the power generator modules (50') with at least one air cooled cell (65') on an upper side forming a deck of the sponson and a closed fresh water circulation loop (68') running between the power generator set and said at least one air cooled cell.

14. The method according to claim 13, further comprising providing at least one fan (67) on an upper side of each of the power generator modules (50; 50') for creating a forced airflow that is directed over the at least one air cooled cell (65').

15. A sponson (10, 20; 10', 20') for converting a Moss type LNG carrier to a floating independent power plant (100; 200) according to the method of claim 11, the sponson being subdivided into a plurality of substantially equally sized compartments (50, 60; 50') along a longitudinal direction of the sponson and arranged to receive a plurality of power generator modules (50; 50') each holding one power generator module (51), arranged such that adjoining power generating modules (50; 50') are mirrored around their adjoining wall, the sponson comprising at least one funnel of exhaust pipes (55) for combining the outlets of adjoining power generator modules and said sponson being adapted for being fixedly mounted on a side of the hull of the Moss type LNG carrier.