VESSEL FOR PRODUCING HYDROCARBONS PROVIDED WITH MEANS FOR SEPARATION OF HYDROCARBONS INTO GASEOUS HYDROCARBONS AND NON GASEOUS HYDROCARBONS AND A METHOD FOR OPERATING SUCH A VESSEL

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ABSTRACT

A vessel for producing hydrocarbons, the vessel being adapted to be connected to at least one riser for transport of the hydrocarbons from a well on the seabed towards the vessel, wherein the vessel includes a separation station for separation of the hydrocarbons into gaseous hydrocarbons and non-gaseous hydrocarbons, storing elements for storing the hydrocarbons and processing elements for processing at least part of the hydrocarbons. The vessel further includes a positioning system for controlling the position and orientation of the vessel with respect to the seabed, wherein the positioning system includes a Dynamic Positioning (DP) system allowing the control of the position and the orientation of the vessel with respect to the seabed without the use of mooring lines, wherein the DP system is adapted to be driven by at least a portion of the gaseous part of the hydrocarbons separated in the separation station.
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[0001] The present invention relates to a vessel for producing hydrocarbons, the vessel being adapted to be connected to at least one riser for transport of the hydrocarbons from a well on the seabed towards the vessel, wherein the vessel comprises a separation station for separation of the hydrocarbons into gaseous hydrocarbons and non-gaseous hydrocarbons, storing means for storing the hydrocarbons and processing means for processing at least part of the hydrocarbons, wherein the vessel comprises a positioning system for controlling the position and orientation of the vessel with respect to the seabed.

[0002] The vessel according to the present invention could be used as a FPSO for smaller, deep water oil fields. The vessel according to the invention is specifically adapted to be used as dynamically positioned Extended Well Testing (EWT) FPSO.

[0003] During the production of oil, using a FPSO-type vessel for offshore oil production, both liquid and gaseous hydrocarbons will be produced. If the quantity of gaseous hydrocarbons produced is sufficiently large, specific measures could be taken to transport the produced gas via adapted transport means, such as a pipeline, to a shore-based or other gas processing facility. However, if the quantity of gas produced is not sufficiently large, the vessel for the production of the offshore oil needs to be equipped with processing means in order to be able to dispose on-board processed gaseous hydrocarbons.

[0004] According to the prior art, several processing methods and devices are available to process a quantity of gas that is produced as a by-product during the oil production. One of the most economical solutions, a solution which has been often used in the past, is to flare the gas. This means that the gas is burnt on board of the vessel. For environmental reasons, the flaring of gas is certainly not the most preferred option and in many areas of the world, the flaring of gas is either prohibited or subject to flaring penalties.

[0005] The problems related to the production of gas as a by product will not only occur during the actual oil production on board of an FPSO. Field operators depend on Extended Well Testing (EWT) in order to obtain data related to the reservoir flow characteristics for a specific oil well. During a limited time period, a vessel which is adapted for the Extended Well Testing (EWT) will be used to produce smaller quantities of oil and at the same time data on the conditions of the well. If the results of the tests are positive, the vessel for Extended Well Testing (EWT) will be replaced by a larger floating facility (e.g. a FPSO) to start actual production of oil. During the operation of the vessel for Extended Well Testing (EWT) the gaseous hydrocarbons that are produced as a by product must be disposed of.

[0006] In normal operation of a vessel used for Extended Well Testing (EWT) a certain volume of oil will be produced from the oil field via subsea production wells. This oil will be transferred to the vessel using conventional transfer means, such as a riser. The oil will be processed on board, after which stabilised oil product will be exported through the offloading system of the vessel to either a shuttle or an opportunity tanker for transport to an onshore terminal.

[0007] During the production of the oil associated gas will also be freed. This gas will contain gaseous hydrocarbons and forms a by-product that needs to be treated on board of the vessel. Since the quantity of gas that is produced on an Extended Well Testing (EWT) vessel is relatively limited, it is not economically feasible to provide transport means, such as a sea floor gas pipeline, to transport the gas to a shore-based or other gas processing facility.

[0008] Since the flaring of the gas is no longer an option, alternative solutions should be used for processing of the gaseous hydrocarbons. An alternative to flaring could be the injection of the gaseous hydrocarbons in the oil via a well. The disadvantage of this technique is the need of relatively large and costly compressors on board of a vessel as well as an injection well system and an associated infrastructure connecting the vessel to an injection well.

[0009] A further alternative would be to use gas-to-liquid (GTL) technology in order to further process the gaseous hydrocarbons on board and to produce a liquid and product which is known in the art as “syn-crude”. However, current onshore GTL conversion plants are relatively expensive and extremely large and therefore unsuited to installation on relatively small floating platforms and vessels of the type used for Extended Well Testing (EWT).

[0010] A disadvantage of this technology is that large and costly process devices are needed to perform the traditional transfer of gas to liquid.

[0011] The invention is aimed to providing a solution to control the energy balance on board of a vessel, in particular a vessel adapted for Extended Well Testing (EWT), wherein at least part of the gaseous hydrocarbons are used as an energy resource on board of the vessel.

[0012] The invention relates to a vessel for producing hydrocarbons, the vessel being adapted to be connected to a riser for transport of the hydrocarbons from a well on the seabed towards the vessel, wherein the vessel comprises a separation station for separation of the hydrocarbons into gaseous hydrocarbons and non-gaseous hydrocarbons, storing means for storing the hydrocarbons and processing means for processing at least part of the hydrocarbons, wherein the vessel comprises a positioning system for controlling the position and orientation of the vessel with respect to the seabed, wherein the positioning system for the vessel comprises a Dynamic Positioning (DP) system allowing the control of the position and the orientation of the vessel with respect to the seabed without the use of mooring lines, wherein the DP system is adapted to be driven by at least a portion of the gaseous part of the hydrocarbons separated in the separation station.

[0013] According to a preferred embodiment of the invention, the DP system comprises a plurality of thrusters and the gaseous part of the hydrocarbons separated in the separation station is used for driving the plurality of thrusters.

[0014] According to a preferred embodiment of the invention, the DP system comprises at least an integrated multi-Fuel reciprocating engine generation system, for example a dual or tri-fuel engine.

[0015] According to a preferred embodiment of the invention, the vessel comprises at least a first power generator set for energizing the DP system and at least a second power generator set for energizing the processing means for processing at least part of the hydrocarbons.
According to a preferred embodiment of the invention, the power generated set for energizing the DP system comprises four power generators.

According to a preferred embodiment of the invention, the power generator set for energizing the DP system is placed in the front part of the vessel for having an air intake at the front of the vessel.

According to a preferred embodiment of the invention, the processing means further comprise means for liquefying at least a portion of the gaseous part of the hydrocarbons.

According to a preferred embodiment of the invention, the processing means further comprise a nitrogen station for the production of nitrogen, wherein the nitrogen station is linked to the means for liquefying at least a portion of the gaseous part of the hydrocarbons in order to use residual heat produced in the liquefying process to generate electricity for driving the nitrogen station.

According to a preferred embodiment of the invention, the vessel further comprises a fresh water station for the production of fresh water wherein the fresh water station is linked to the means for liquefying at least a portion of the gaseous part of the hydrocarbons in order to use residual heat produced in the liquefying process for driving the fresh water station.

According to a preferred embodiment of the invention, the vessel is provided with a riser balcony placed at the one side of the vessel, wherein the riser balcony is adapted to be connected via a bearing to the at least one riser.

According to a preferred embodiment of the invention, the vessel is adapted to be connected to a riser having an upper riser end which is provided with a buoy and a quick disconnect system.

According to a preferred embodiment of the invention, the vessel is an Extended Well Testing (EWT) FPSO.

The invention also relates to a method for operating a vessel for the production of hydrocarbons wherein the vessel is adapted to be connected to at least one riser for transport of the hydrocarbons produced by said vessel from one or more wells on the seabed towards the vessel and wherein the vessel comprises a separation station for separation of the hydrocarbons into gaseous hydrocarbons and non-gaseous hydrocarbons, storing means for storing the hydrocarbons and processing means for processing at least part of the hydrocarbons, wherein the vessel further comprises a positioning system for controlling the position and orientation of the vessel with respect to the seabed, and wherein the method for operating the vessel comprises the steps of:

- controlling the position and the orientation of the vessel with respect to the seabed by means of a Dynamic Positioning (DP) system, comprising a plurality of thrusters,
- driving the plurality of thrusters of the DP system by means of at least a portion of the gaseous part of the hydrocarbons separated in the separation station.

According to a preferred embodiment of the invention, a further portion of the gaseous part of the hydrocarbons separated in the separation station is liquefied using a gas-to-liquid (GTL) process, wherein the process means on the vessel further comprise a nitrogen station for the production of nitrogen and wherein residual heat produced in the GTL process is used for creating electricity for driving the nitrogen station.

According to a preferred embodiment of the invention, the vessel further comprises a fresh water station for the production of fresh water wherein residual heat produced in the GTL process is used for driving the clean water station.

The invention and the advantages of the invention will be better explained in detail in the description of a preferred embodiment of the invention wherein reference is made to the accompanying drawings, wherein:

FIG. 1 schematically shows a vessel and the different influences of wind and current on the bow of the vessel.

FIG. 2 shows an embodiment of the vessel according to the invention (seen from above).

FIG. 3 shows the vessel according to FIG. 2 in a front view.

FIG. 1 shows schematically a vessel wherein different influences of wind and current are shown. The vessel 1 is exposed to the influence of the wind 2. Moreover, the current 3 and the waves 4 will have an influence on the positioning of the vessel 1 with respect to the seabed.

The vessel 1 will be provided with a main propulsion 5 provided at the aft of the vessel 1 which will be used to sail to side or in the disconnect mode to sail to a yard for maintenance and change out purposes. The vessel 1 is also provided with additional thrusters schematically indicated with reference numbers 6 and 7.

These thrusters 6, 7 comprise for instance azimuth thrusters for keeping the vessel 1 at a preferred position (station keeping) and for heading control.

In FIG. 2, a preferred embodiment of the vessel 10 according to invention is shown. In FIG. 3 the vessel 10 is shown in front view.

The vessel 10 is provided with devices and installations in order to allow the vessel 10 to be used for Extended Well Testing (EWT). The installations on board of the vessel comprise, among others:

- devices for separation of produced hydrocarbons into a first liquid fraction and a second gaseous fraction,
- a dynamic positioning (DP) system, for allowing the vessel to be positioned with respect to the seabed without the need of using mooring lines, wherein the DP system is adapted to be, at least partially, driven by means of the gaseous fraction of the hydrocarbons,
- devices for liquefying at least a part of the gaseous fraction of the hydrocarbons,
- a production system for producing clear water on board, wherein the fresh water production system is adapted to be connected to the devices for liquefying at least part of the gaseous fraction of the hydrocarbons, in order to allow the fresh water production system to be at least partially driven by waste heat produced by the devices for liquefying at least a part of the gaseous fraction of the hydrocarbons.

The vessel 10 will be fitted with an external riser turret located mid-ship on the starboard side of the vessel 10. In FIG. 2 the riser balcony 11 is shown, positioned mid-ships on the starboard side. This location is preferred for the Dynamically Positioned (DP) facilities as the vessel will pivot around the centre point, thus the risers will be subjected to less movement and deviation when located at this midships location. The vessel 10 will be adapted to be used in combination with a riser having an upper riser end which is provided with a buoy and a quick disconnect system.

The vessel 10 is provided with at least two power generator sets. A first power generator set is specifically dedicated to energizing the DP system. A second power generator set is used for energizing the process plant (for redundancy).
According to a preferred embodiment of the invention, the DP system for the vessel 10 comprises six internally mounted azimuthing thrusters that as an option are of a retractable type.

[0044] According to the invention, the power generator set for energizing the DP system is placed in the front part of the vessel 10. This power generator set is preferably placed below deck level in order to leave more space available for the different process plants on deck level. The position of the generator set for the DP system at the front part of the vessel 10 has the advantage that the air intake of the generator set will also be at the front of the vessel 10. This means that the air intake is positioned before the process plants and that therefore, relatively clean air can be taken in for the power generators; this ensures that station keeping power is always maintained.

[0045] The power generator set for energizing the DP system comprises, in a preferred embodiment, four power generators of each 11 MW. The advantage of using four generators is that in steady state two generators will be running, while one generator will be available as spare. The forth generator is available for maintenance.

[0046] Alternatively, the riser turret could be positioned on the bow of the vessel 10 as per conventional layout. This option could be chosen if this option proves of major benefit to the overall design, such as freeing up deck space. In that case the position of the power generator set for the DP system will have to be adapted to allow this alternative position of the turret.

[0047] The riser turret for the vessel 10 will be based on a total of six riser slots consisting of two production risers plus two umbilicals and two additional slots. The additional two riser slots will be used as service lines or may be used to allow tie-in of an additional well and control umbilical with the same configuration if required. The production is expected to come from a single production well. An additional allowance for two or more risers, including umbilicals, is therefore provided.

[0048] Oil is assumed to be produced from one or two individual subsea wells which will be tied back via independent flow lines and risers to the vessel 10. The conventional Brazilian operations approach to subsea architecture could be used, with one production riser, one service riser and one control umbilical per well.

[0049] The turret includes a toroidal-swivel and a separate pipe-swivel for the two individual production risers. The service lines and umbilicals are expected to be routed via dedicated paths located within a utility swivel. Alternatively, a non-rotatable fluid transfer system can be used that does not comprise a rotatable turret and swivels.

[0050] During the operation of the vessel 10 according to FIGS. 2 and 3, a certain amount of oil will be produced from a well. The vessel 10 is equipped with devices for obtaining data relating to the conditions of the well. These data will be used to review the potential of the well and the amount of oil that can be produced by the well. The vessel 10 will be used until sufficient data are available to be able to decide whether the well is suitable for economical oil production or not. If the results of the test are positive, the vessel 10 will be removed and replaced by a larger FPSO, which will be adapted for long term oil production.

[0051] The vessel 10 according to FIGS. 2 and 3 will be equipped with a separator for separating the hydrocarbons that are produced by the vessel 10 into a first, liquid fraction comprising liquid hydrocarbons and a second, gaseous fraction comprising gaseous hydrocarbons.

[0052] The liquid hydrocarbon fraction will be stored on board of the vessel 10 and will be off loaded using conventional techniques. The gaseous fraction will be used for at least two different purposes.

[0053] A first part of the gaseous hydrocarbon fraction will be used for energizing the dynamic positioning (DP) system. This means in practice that this first part of the gaseous fraction of hydrocarbons will be used for driving the azimuthing thrusters of the DP system.

[0054] The fact that at least part of the gaseous fraction is directly used for the DP system, means that the vessel 10 according to the invention is capable of using this part of the gaseous fraction of the hydrocarbons during its normal operation. Therefore, during the normal operation of the vessel 10 the gaseous hydrocarbons that are used as a by-product do no longer create a problem on board of the vessel, but are used as a source of energy for the on board processes, which will lead to an important improvement of the control of the energy balance on board of the vessel 10. The part of the gaseous hydrocarbons that is used for driving the DP system no longer needs to be processed on board of the vessel.

[0055] A second part of the gaseous hydrocarbon will be processed on board and will be treated by means of a GTL process. The effect of this GTL process is that the gaseous hydrocarbons are transferred into an end product which is liquid at ambient temperature and which can be stored more easily on board of the vessel and which can, in due course, be off loaded using conventional off-loading techniques.

[0056] In order to allow the liquefying of part of the gaseous fraction the vessel 10 according to FIGS. 2 and 3 is equipped with an on board GTL installation.

[0057] The fact that on board GTL is possible, is related to the fact that recently gas-to-liquid (GTL) processes have become available, which are significantly more compact than conventional facilities and that are suitable for processing relatively small amounts of gas, typical of the amount that is produced on an Extended Well Testing (EWT) vessel.

[0058] These relatively compact processes for GTL can only be achieved by integrating two processes: crude oil treating and GTL. The combination of the two processes is needed, such that a sufficient degree of synergy is achieved by sharing process functions and components. This synergy will allow the installations to stay within the given limits of size, weight and safety needed for the use on board of the GTL installation.

[0059] The conversion of gas to liquids (GTL) is commonly accomplished by variations of the Fischer-Tropsch (FT) process. According to this FT process a synthetic gas called Syngas (which is a mixture of carbon monoxide and hydrogen) is first created from hydrocarbon gas. This Syngas is then converted using catalysts to obtain longer chain hydrocarbon molecules which are liquid at ambient temperature. Alternative gas to liquid processes are known and can be applied on a EWT vessel according the invention.

[0060] The conversion of natural gas consists of two stages of catalytic reactions. The first stage comprises the conversion from natural gas, mainly methane, to Syngas. This process is most effectively achieved by using the STEAM METHANE REFORMING (SMR) followed by the Fischer-Tropsch (FT) reaction itself.
The resulting liquid is a mixture of various hydrocarbons, consisting mainly of paraffinic molecules, which is termed Syncrude.

The close relationship between the two reactors in the GTL process is an important aspect in the management of the overall system and in allowing the system to be sufficiently compact to be used on board of a vessel such as an FPSO for Extended Well Testing (EWT).

A detailed description of a preferred embodiment of some of the process installations on board of the vessel 10 is provided below.

On board of the vessel 10 a high operating pressure (HP) is used for the HP separator in order to allow some Joule-Thomson (JT) treating of the associated gas stream, with the objective to achieve additional condensate removal prior to the GTL process.

This high initial HP pressure then favours the installation of a 3-stage degassing system for oil stabilisation. The 3-stage system will improve condensate recovery compared to a 2-stage system and will also distribute overall heating loads required to achieve the condensate RVP and result in lower compression requirements. The oil stabilisation thus contains a HP, IP and LP separator. The HP separator is designed to allow operation at pressures of up to 70 bar in order to provide flexibility for well productivity testing.

The associated gas stream will be used as top-up fuel gas as required for both topsides and marine, that means for the DP power generation, the main fuel gas source being the reject streams from the GTL process. The remaining process gas which is not used as fuel is routed to the GTL process for conversion to liquids.

The main functions of the fuel gas systems are to generate power and to raise steam in auxiliary boilers. To indicate the order of magnitude of possible preliminary power requirements for the vessel 10, the following example is given:

- Topsides Max Power Demand (including GTL Process) up to 50 MW
- Station keeping and marine up to 25 MW
- The power on board is used as:
  - topsides power, which is generated in Gas Turbine Generators (GTTG’s) located on the vessel’s 10 topsides;
  - marine power, including the DP, which is generated in dual fuel engines located in a converted cargo space in the vessel hull. This includes for instance Tri-Fuel Reciprocating Engines generating. The Tri-Fuel Reciprocating Engines generate, for instance, 12 MW each at maximum output rating.

The normal source of fuel gas on conventional FPSO’s is the associated gas from the oil stabilisation process. For the vessel 10 there are additional gas streams which are off-gases from the GTL process. These streams are:

- SMR membrane permeate, and
- FT tail gas.

These gases cannot be consumed elsewhere in the process and must therefore be used as fuel gas. The waste gas streams can be integrated into the overall fuel gas systems. These gases will thus be used as the main source of fuel gas with top up from process gas as required. These GTL off-gas streams will save on the required quantity of associated process gas required for fuel and thus allow this to be fed forward to the GTL process.

The DP system is expected to interface with an Integrated Control and Safety System (ICSS) but shall have an independent power management and thruster control system designed to maintain station keeping with the required level of redundancy independent of topside systems.

A preferred embodiment of the DP system shall comprises, among others, the following equipment arranged to provide optimum redundancy in case of failure:

- Dynamic Positioning Control System,
- Power Generation System (see section 7 power generation),
- Two identical Power Distribution Systems arranged to provide redundancy against any single component failure. These will comprise of a power management system and switchboard units located in the LER and fwd machinery spaces,
- 6x Transformers and Variable Frequency Drives (VFD) located in the LER and fwd machinery spaces,
- 6x Azimuthing Thrusters (Internally or externally mounted/Retractable or non-retractable type).

Due to the active nature of use of the vessel 10 a quick disconnect system shall be included in the riser turret assembly. The risers shall be supported by a buoyant upper riser system or buoy following disconnect with means to recover for re-connection to the unit. As the vessel is DP the mooring securing the buoy to the seabed does not need to support any loads exerted by the vessel.

1. Vessel for producing hydrocarbons, the vessel being adapted to be connected to at least one riser for transport of the hydrocarbons from a well on the seabed towards the vessel, wherein the vessel comprises a separation station for separation of the hydrocarbons into gaseous hydrocarbons and non-gaseous hydrocarbons, storing means for storing the hydrocarbons and processing means for processing at least part of the hydrocarbons, wherein the vessel comprises a positioning system for controlling the position and orientation of the vessel with respect to the seabed, characterised in that, the positioning system comprises a Dynamic Positioning (DP) system allowing the control of the position and the orientation of the vessel with respect to the seabed without the use of mooring lines, wherein the DP system is adapted to be driven by at least a portion of the gaseous part of the hydrocarbons separated in the separation station.

2. Vessel according to claim 1, wherein the DP system comprises a plurality of thrusters and wherein the gaseous part of the hydrocarbons separated in the separation station is used for driving the plurality of thrusters.

3. Vessel according to claim 1, wherein the DP system comprises at least an integrated multi-Fuel reciprocating engine generation system.

4. Vessel according to claim 1, wherein the vessel comprises at least a first power generator set for energizing the DP system and at least a second power generator set for energizing the processing means for processing at least part of the hydrocarbons.

5. Vessel according to claim 4, wherein the power generated set for energizing the DP system comprises four power generators.

6. Vessel according to claim 4, wherein the power generator set for energizing the DP system is placed in the front part of the vessel for having an air intake at the front of the vessel.

7. Vessel according to claim 1, wherein the processing means comprise means for liquefying at least a portion of the gaseous part of the hydrocarbons.
8. Vessel according to claim 7, wherein the processing means further comprise a nitrogen station for the production of nitrogen, wherein the nitrogen station is linked to the means for liquefying at least a portion of the gaseous part of the hydrocarbons in order to use residual heat produced in the liquefying process to generate electricity for driving the nitrogen station.

9. Vessel according to claim 7, wherein the vessel further comprises a fresh water station for the production of fresh water wherein the fresh water station is linked to the means for liquefying at least a portion of the gaseous part of the hydrocarbons in order to use residual heat produced in the liquefying process for driving the fresh water station.

10. Vessel according to claim 1 wherein the vessel is provided with a riser balcony placed at the one side of the vessel, wherein the riser balcony is adapted to be connected via a bearing to the at least one riser.

11. Vessel according to claim 1, wherein the vessel is adapted to be connected to a riser having an upper riser end which is provided with a buoy and a quick disconnect system.

12. Vessel according to claim 1, wherein the vessel is an Extended Well Testing (EWT) FPSO.

13. Method for operating a vessel for the production of hydrocarbons, wherein the vessel is adapted to be connected to at least one riser for transport of the hydrocarbons produced by said vessel from one or more wells on the seabed towards the vessel and wherein the vessel comprises a separation station for separation of the hydrocarbons into gaseous hydrocarbons and non-gaseous hydrocarbons, storing means for storing the hydrocarbons and processing means for processing at least part of the hydrocarbons, wherein the vessel further comprises a positioning system for controlling the position and orientation of the vessel with respect to the seabed, characterised in that, the method for operating the vessel comprises the steps of:
   controlling the position and the orientation of the vessel with respect to the seabed by means of a Dynamic Positioning (DP) system, comprising a plurality of thrusters, driving the plurality of thrusters of the DP system by means of at least a portion of the gaseous part of the hydrocarbons separated in the separation station.

14. Method according to claim 13, wherein a further portion of the gaseous part of the hydrocarbons separated in the separation station is liquefied using a gas-to-liquid (GTL) process, wherein the process means on the vessel further comprise a nitrogen station for the production of nitrogen and wherein residual heat produced in the GTL process is used for generating electricity for driving the nitrogen station.

15. Method according to claim 13, wherein the vessel further comprises a fresh water station for the production of fresh water wherein residual heat produced in the GTL process is used for driving the fresh water station.

16. Vessel according to claim 2, wherein the DP system comprises at least an integrated multi-Fuel reciprocating engine generation system.

17. Vessel according to claim 5, wherein the power generator set for energizing the DP system is placed in the front part of the vessel for having an air intake at the front of the vessel.

18. Vessel according to claim 8, wherein the vessel further comprises a fresh water station for the production of fresh water wherein the fresh water station is linked to the means for liquefying at least a portion of the gaseous part of the hydrocarbons in order to use residual heat produced in the liquefying process for driving the fresh water station.

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