

【DESCRIPTION】**【Invention Title】****LIQUEFIED GAS REGASIFICATION SYSTEM AND METHOD FOR VESSEL****【Technical Field】**

[1] The present invention relates to a liquefied gas regasification system and method for vessels, which generate power by recovering cold heat discarded in regasification of liquefied gas to improve energy efficiency.

【Background Art】

[2] LNG regasification vessels or floating offshore structures (hereinafter, commonly referred to as "LNG regasification vessels"), such as LNG regasification vessels (LNG RVs) or floating storage and regasification units (LNG FSRUs), are directed to supply natural gas obtained through regasification of liquefied natural gas (LNG) at sea to onshore gas consumers.

[3] Such an LNG regasification vessel is provided with an LNG storage tank adapted to store LNG and a regasification facility adapted to supply natural gas to a gas demand site on land through regasification of the LNG stored in the LNG storage tank, in which the natural gas generated by the regasification facility is supplied to onshore gas consumers through pipes.

[4] The regasification facility of the LNG regasification vessel includes a high-pressure pump compressing LNG stored in the LNG storage tank to a pressure required for an onshore gas consumer and a vaporizer gasifying the high pressure LNG compressed by the high pressure pump into natural gas.

[5] For easy supply, seawater is mainly used as a heat source for gasification of LNG in the vaporizer.

[6] An LNG regasification system using seawater as a heat source may be classified into a direct heat exchange type in which LNG is gasified through direct heat exchange between seawater and LNG in the vaporizer, and an indirect heat exchange type in which a separate heating medium is heated through heat exchange

with seawater and LNG is gasified through heat exchange between LNG and the heating medium heated by the seawater.

[7] Despite good heat transfer efficiency through direct transfer of heat energy of seawater to LNG, the direct heat exchange type has a problem of freezing the seawater in the heat exchanger.

[8] Although the indirect heat exchange type can prevent the problem of freezing the seawater, the indirect heat exchange type has lower heat exchange efficiency than the direct heat exchange type due to heat exchange between the seawater and the heating medium.

[9] Moreover, low-temperature seawater having cold heat recovered from LNG through direct or indirect heat exchange with LNG is discharged back to the sea. That is, in the process of regasifying the LNG, the cold heat of the LNG recovered by the seawater is discarded to sea as is.

[10] In general, natural gas is transported to a distant destination by an LNG carrier after being transformed into liquefied natural gas (LNG) through liquefaction at extremely low temperatures at a production site. LNG is obtained by cooling natural gas to a cryogenic temperature of about -163°C and has a volume of about 1/600 that of natural gas in a gaseous state. Thus, LNG is suited to long distance transport by sea.

[11] A process of generating LNG through liquefaction of natural gas requires a large quantity of energy, in which LNG has a cold-heat energy of 200 kcal/kg.

[12] That is, in the process of regasifying LNG, the cold heat of LNG recovered by seawater is discarded to sea as is.

【Disclosure】

【Technical Problem】

[13] Embodiments of the present invention provide a liquefied-gas regasification system and method for vessels, which can generate power by recovering cold heat discarded in regasification of liquefied gas to improve energy efficiency and can supply natural gas to gas consumers through stable regasification of the liquefied gas.

【Technical Solution】

[14] In accordance with one aspect of the present invention, there is provided a liquefied-gas regasification system for vessels, including: a high-pressure pump pressurizing the liquefied gas to a pressure range required for the gas consumer; a vaporizer gasifying liquefied gas pressurized using the high-pressure pump into a regasified gas through heat exchange with a first heating medium; a trim heater heating the regasified gas to a temperature required for a gas consumer through heat exchange with a second heating medium when the regasified gas is delivered from the vaporizer to the gas consumer; a first heat exchanger gasifying the first heating medium condensed by heat exchanging with the liquefied gas in the vaporizer through heat exchange with a heat source; an expander-generator generating power through expansion of the first heating medium gasified by the first heat exchanger; a first heating medium line delivering the first heating medium expanded using the expander-generator to the vaporizer, and a second heat exchanger heating the second heating medium to be supplied to the trim heater through heat exchange with a heat source, wherein the first heating medium is undergoing phase change while circulating through the vaporizer and the first heat exchanger, and the second heating medium is not undergoing change while circulating through the trim heater and the second heat exchanger.

[15] The heat source may include one of seawater and steam.

[16] The liquefied-gas regasification system may further include a seawater pump suctioning and supplying seawater as the heat source to the first heat exchanger and the second heat exchanger, wherein the seawater pump, the first heat exchanger and the second heat exchanger are disposed under a deck of the vessel, and the vaporizer and the trim heater are disposed on an upper deck of the vessel.

[17] The first heating medium may be a refrigerant undergoing phase change while circulating in the first cycle and may be selected from among a natural refrigerant, an HFO-based refrigerant, an HFC-based refrigerant, and a mixture

thereof not providing fire and explosion risks.

[18] The second heating medium may be glycol water.

[19] The liquefied-gas regasification system may further include a first branch-off line branched off upstream of the expander-generator from a first heating medium line connected to the expander-generator to deliver the first heating medium gasified by the first heat exchanger to the expander-generator, wherein the first branch-off line is connected to the vaporizer such that the first heating medium supplied to the expander-generator is supplied to the vaporizer after bypassing the

expander-generator along the first branch-off line.

[20] The liquefied-gas regasification system may further include: a high-pressure pump compressing the liquefied gas to a pressure required for the gas consumer to supply the compressed liquefied gas to the vaporizer; and a first valve controlling a flow rate of the liquefied gas supplied from the high-pressure pump to the vaporizer.

[21] The liquefied-gas regasification system may further include: a first temperature measurement unit measuring a temperature of natural gas supplied from the trim heater to the gas consumer; a first pressure measurement unit measuring a pressure of the natural gas supplied from the trim heater to the gas consumer; a first flow rate measurement unit measuring a flow rate of the natural gas supplied from the trim heater to the gas consumer; and a first controller regulating a regasified amount of the liquefied gas by regulating an opening degree of the first valve depending upon any one selected from among the temperature measured by the first temperature measurement unit, the pressure measured by the first pressure measurement unit and the flow rate measured by the first flow rate measurement unit.

[22] The liquefied-gas regasification system may further include: a second temperature measurement unit measuring a temperature of the second heating medium discharged from the trim heater and cooled through heat exchange; and a first controller regulating a regasified amount of the liquefied gas by regulating an opening degree of the first valve depending upon the temperature measured by the second temperature measurement unit.

[23] The liquefied-gas regasification system may further include: a first temperature measurement unit measuring a temperature of natural gas supplied from the trim heater to the gas consumer; a second temperature measurement unit measuring a temperature of the second heating medium discharged from the trim heater and cooled through heat exchange; at least one selected from among a first pressure measurement unit measuring a pressure of the natural gas supplied from the trim heater to the gas consumer and a first flow rate measurement unit measuring a flow rate of the natural gas supplied from the trim heater to the gas consumer; and a first controller regulating an opening degree of the first valve based on the smallest

value selected from among an opening degree of the first valve for maintaining the temperature measured by the first temperature measurement unit within a predetermined range, an opening degree of the first valve for maintaining the temperature measured by the second temperature measurement unit within a predetermined range, and an opening degree of the first valve for maintaining at least one of the pressure measured by the first pressure measurement unit and the flow rate measured by the first flow rate measurement unit within a predetermined range.

[24] The liquefied-gas regasification system may further include: a receiver receiving the first heating medium condensed in the course of gasifying the liquefied gas in the vaporizer; a second branch-off line branched off upstream of the vaporizer from the first heating medium line delivering the first heating medium to the vaporizer such that the first heating medium is supplied to the receiver after bypassing the vaporizer along the second branch-off line; a second pressure measurement unit measuring a pressure of the receiver; and a second controller regulating an opening degree of a second valve disposed on the second branch-off line depending upon the pressure measured by the second pressure measurement unit.

[25] The liquefied-gas regasification system may further include: a receiver receiving the first heating medium condensed in the course of gasifying the liquefied gas in the vaporizer; a second branch-off line branched off upstream of the vaporizer from the first heating medium line delivering the first heating medium to the vaporizer such that the first heating medium is supplied to the receiver after bypassing the vaporizer along the second branch-off line; a third temperature controller measuring a temperature of the regasified gas supplied from the vaporizer to the trim heater; and a second controller regulating an opening degree of a second valve disposed on the second branch-off line depending upon the temperature measured by the third temperature controller.

[26] The liquefied-gas regasification system may further include: a receiver receiving the first heating medium condensed in the course of gasifying the liquefied gas in the vaporizer; a second branch-off line branched off upstream of the vaporizer from the first heating medium line delivering the first heating medium to the

vaporizer such that the first heating medium is supplied to the receiver after bypassing the vaporizer along the second branch-off line; a second valve disposed on the second branch-off line and allowing regulation of an opening degree thereof; a second pressure measurement unit measuring a pressure of the receiver; a third temperature controller measuring a temperature of the regasified gas supplied from the vaporizer to the trim heater; and a second controller regulating an opening degree of the second valve based on a smaller value selected from among an opening degree of the second valve for maintaining the pressure measured by the second pressure measurement unit within a predetermined range and an opening degree of the second valve for maintaining the temperature measured by the third temperature controller within a predetermined range.

[27] In accordance with another aspect of the present invention, there is provided a liquefied-gas regasification method for vessels, including: pressurizing the liquefied-gas to a pressure range required for the gas consumer; gasifying the pressurized liquefied gas through heat exchange with a first heating medium; and heating the regasified gas by heat exchanging with the first heating medium to a temperature required for a gas consumer through heat exchange with a second heating medium, gasifying the first heating medium condensed by heat exchanging with the liquefied gas through heat exchange with a heat source expanding the gasified first heating medium using an expander-generator to generate power and subjected to heat exchange with the liquefied gas, wherein the first heating medium circulates in a closed cycle while heat exchanging with the liquefied gas and the heat source and undergoes phase change while circulating the closed cycle, and the second heating medium circulates in a closed cycle while heat exchanging with the regasified gas and the heat source and does not undergo change while circulating through the closed cycle.

[28] A heat source for heating the first heating medium and the second heating

medium may be seawater, steam, or a combination of seawater and steam; the first heating medium may be a refrigerant undergoing phase change while circulating in the first cycle and may be selected from among a natural refrigerant, an HFO-based refrigerant, an HFC-based refrigerant, or a mixture thereof not providing fire and explosion risks; and the second heating medium may be glycol water.

[29] The liquefied gas to be regasified may be compressed to a pressure required for the gas consumer and subjected to heat exchange with the first heating medium; and a flow rate of the liquefied gas to be subjected to heat exchange with the first

heating medium may be controlled based on a measured value obtained by measuring at least one selected from among a pressure, a temperature and a flow rate of the regasified gas heated through heat exchange with the second heating medium and supplied to the gas consumer.

[30] The liquefied gas to be regasified may be compressed to a pressure required for the gas consumer and subjected to heat exchange with the first heating medium; and a flow rate of the liquefied gas to be subjected to heat exchange with the first heating medium may be controlled based on a measured value obtained by measuring a temperature of the second heating medium cooled while heating the regasified gas.

[31] The first heating medium condensed in the course of gasifying the liquefied gas may be stored in the receiver and resupplied to the vaporizer after heat exchange with the heat source; and a flow rate of the first heating medium to be directly supplied to the receiver without heat exchange with the liquefied gas may be controlled depending upon at least one measurement value selected from among a pressure measurement value of the receiver and a temperature measurement value of the regasified gas to be subjected to heat exchange with the second heating medium.

【Advantageous Effects】

[32] Embodiments of the present invention provide a liquefied-gas regasification system and method for vessels, which can improve energy efficiency while reducing fuel consumption for power generation and suppressing discharge of greenhouse gases through generation of power by recovering cold heat discarded in regasification of liquefied gas.

[33] In addition, even when heat capacity of a first heating medium is insufficient in a vaporizer, a regasified gas can be stably supplied to gas consumers after being heated to the minimum delivery temperature or more using a trim heater.

[34] Further, with the trim heater, the regasification system and method can prevent insufficient gasification of liquefied gas due to thermal unbalance between a supply amount of the liquefied gas and a supply amount of the first heating medium in a loop cycle of the first heating medium in an initial operation stage of the

regasification system, thereby enabling stable operation of the regasification system.

[35] Further, in the regasification system, the first heating medium and the second heating medium heated through heat exchange with seawater under a deck are supplied to the vaporizer on an upper deck, thereby enabling reduction in power consumption through reduction in minimum head of a seawater pump for suctioning seawater.

【Description of Drawings】

[36] FIG. 1 is a schematic diagram of a liquefied gas regasification system of a vessel according to one embodiment of the present invention.

[37] FIG. 2 is a schematic diagram of the liquefied gas regasification system shown in FIG. 1, illustrating some components of the liquefied gas regasification system including a temperature controller.

[38] FIG. 3 is a Q-T (heat quantity-temperature) graph when a first heating medium, that is, a refrigerant, is used as a heat source in a trim heater according to the embodiment of the present invention.

[39] FIG. 4 is a Q-T (heat quantity-temperature) graph when a second heating medium, that is, glycol water, is used as a heat source in the trim heater according to the embodiment of the present invention.

【Best Mode】

[40] The above and other aspects, features, and advantages of the present invention will become apparent from the detailed description of the following embodiments in conjunction with the accompanying drawings.

[41] Embodiments of the present invention will be described with reference to the accompanying drawings. It should be noted that like components will be denoted by like reference numerals throughout the specification and the accompanying drawings. In addition, description of known functions and constructions which may unnecessarily obscure the subject matter of the present invention will be omitted. Moreover, description of known functions and constructions which may unnecessarily obscure the subject matter of the present invention will be omitted.

Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. However, it should be understood that these embodiments are not to be construed in any way as limiting the present invention, and that various modifications, changes, alterations, and equivalent embodiments can be made by those skilled in the art without departing from the spirit and scope of the invention.

[42] As used herein, "liquefied gas" may refer to a gas that can be transported in liquid form by being liquefied at low temperature, for example, liquefied petrochemical gas, such as liquefied natural gas (LNG), liquefied ethane gas (LEG), liquefied petroleum gas (LPG), liquefied ethylene gas, and liquefied propylene gas. In addition, "liquefied gas" may also refer to a gas in a liquid state, such as liquefied carbon dioxide, liquefied hydrogen, and liquefied ammonia. However, the following embodiments will be described using LNG, which is a typical liquefied gas, by way of example.

[43] Although an LNG regasification vessel according to embodiments of the present invention will be described as applied to vessels, it will be understood that the LNG regasification vessel according to the embodiments of the present invention may also be applied to onshore facilities.

[44] In addition, in one embodiment of the invention, an LNG regasification vessel may include any ship that is provided with an LNG regasification facility to regasify LNG and supply the regasified LNG to gas consumers, including self-propelled ships, such as LNG regasification vessels (RVs), and floating offshore structures, such as floating storage regasification units (FSRUs). Further, in the following embodiments, the LNG regasification vessels may refer to LNG FSRUs by way of example.

[45] Further, the LNG regasification vessel according to the embodiments of the invention may regasify LNG at sea to supply the regasified LNG to onshore gas consumers via a pipe network (regas network).

[46]

[47] A liquefied gas regasification system and method for vessels according to one embodiment will be described with reference to FIG. 1 to FIG. 4.

[48] An LNG regasification vessel according to one embodiment of the present invention may include an LNG storage tank (not shown) that stores LNG, a boil-off processing unit (not shown) that processes boil-off gas (BOG) generated in the LNG storage tank, a bunkering unit (not shown) that loads LNG to the LNG storage tank or unloading LNG stored in the LNG storage tank, and a regasification system that gasifies LNG stored in the LNG storage tank to supply regasified LNG to an onshore gas consumer (jetty).

[49] The LNG regasification vessel according to the embodiment of the present invention can perform an LNG loading/unloading process of the LNG storage tank and an LNG regasification process.

[50] The LNG storage tank may be provided in plural and LNG may have a temperature of about -161°C and may be stored under a pressure of 1.1 bar in the LNG storage tank. Since LNG has a vapor pressure higher than atmospheric pressure and a boiling point of about -163°C , LNG must be safely stored in order to use LNG in a vessel. Therefore, the LNG storage tank according to this embodiment requires LNG storage, temperature maintenance, and airtight functions. To this end, the LNG storage tank may include an insulating material and auxiliary equipment to maintain the cryogenic temperature of LNG by blocking heat inflow from an outside. In addition, the LNG storage tank may be formed of a special material that can withstand extremely low temperatures.

[51] The BOG processing unit may process boil-off gas generated when LNG is loaded into the LNG storage tank and boil-off gas generated through natural vaporization of the LNG stored in the LNG storage tank.

[52] The BOG processing unit may include a low pressure compressor (not shown) that compresses boil-off gas discharged from the LNG storage tank to a pressure required for an engine and supplies the boil-off gas as fuel for the engine. In addition, the BOG processing unit may further include a fuel heater (not shown) for heating the boil-off gas compressed by the low-pressure compressor to a temperature required for the engine.

[53] The engine may be a low-pressure engine, for example, a dual fuel diesel electric (DFDE) engine capable of generating power using boil-off gas as fuel.

[54] The BOG processing unit may further include a condenser (not shown) that mixes LNG with the boil-off gas compressed by the low-pressure compressor and condenses the boil-off gas mixed with LNG.

[55] The boil-off gas condensed by the condenser, that is, LNG, may be recovered by the LNG storage tank or may be supplied to a high-pressure pump 110 of a regasification system described below. LNG supplied to the condenser may be LNG supplied from the LNG storage tank to the high-pressure pump 110 or LNG compressed by the high-pressure pump 110.

[56] On the other hand, a pressure upstream of the high-pressure pump 110 may be regulated using the condenser as a suction drum by regulating the flow rate of LNG supplied from the condenser to the high-pressure pump 110.

[57] The BOG processing unit may further include a high-pressure compressor (not shown) that compresses the boil-off gas discharged from the LNG storage tank to a pressure required for a gas consumer to supply the compressed boil-off gas together with the regasified gas to the gas consumer.

[58] Referring to FIG. 1 and FIG. 2, a liquefied gas regasification system for vessels according to one embodiment includes the high-pressure pump 110 that compresses LNG stored in the LNG storage tank at least to a pressure required for a gas consumer, a vaporizer 120 that gasifies the high pressure LNG compressed by the high pressure pump 110, and a trim heater 130 that regulates the temperature of the regasified gas gasified by the vaporizer 120, that is, natural gas, to a temperature required for the gas consumer or completely gasifies LNG not gasified by the vaporizer 120 and heats the LNG to the temperature required for the gas consumer.

[59] Further, the liquefied gas regasification system according to the embodiment includes a first cycle in which a first heating medium is circulated as a heat source for gasification of LNG through heat exchange with LNG in the vaporizer 120, a second cycle in which a second heating medium is circulated as a heat source for heating natural gas in the trim heater 130, and a seawater pump 410 that supplies seawater as a heat source for heating the first heating medium circulated in the first cycle and the second heating medium circulated in the second cycle.

[60] Further, the LNG storage tank may be provided with a supply pump (not shown) by which LNG stored in the LNG storage tank is discharged and supplied to the high-pressure pump 110. The power pump may be an in-tank pump disposed in the LNG storage tank or a submersible pump that can be operated in a state of being submerged in LNG stored in the LNG storage tank.

[61] According to this embodiment, the high-pressure pump 110 compresses LNG to a pressure of the regasified gas required for the gas consumer to supply the compressed LNG to the vaporizer 120. Although the pressure required for the gas consumer differs according to each jetty, the pressure required for the gas consumer is generally in the range of about 50 bar to about 100 bar. That is, the high-pressure pump 110 according to this embodiment may compress LNG to a pressure of about 50 bar to about 100 bar or a higher pressure than this pressure in consideration of pressure loss.

[62] According to this embodiment, in the vaporizer 120, the high pressure LNG compressed to the pressure of the regasified gas required for the gas consumer by the high-pressure pump 110 may be gasified into a gas phase or may be partially gasified into a mixed phase of gas and liquid through heat exchange with the first heating medium circulating in the first cycle. The temperature of the compressed LNG vaporized by the vaporizer 120 may vary depending upon the conditions of the heat source, such as the temperature or the flow rate of the first heating medium and/or seawater.

[63] The vaporizer 120 according to this embodiment may be a shell & tube heat exchanger, particularly a 1-pass type shell & tube heat exchanger in which a tube passes through a shell once.

[64] In the trim heater 130 according to this embodiment, the regasified gas gasified by the vaporizer 120 is heated to a temperature required for the gas consumer and supplied to the gas consumer. In addition, when there is LNG not gasified by the vaporizer 120 due to lack thermal capacity of the first heating medium, all LNG may be gasified and heated to a temperature required for the gas consumer by the trim heater 130.

[65] The trim heater 130 according to this embodiment may be a shell & tube

heat exchanger, particularly a 2-pass type shell & tube heat exchanger in which a tube passes through a shell twice.

[66] Since an onshore gas consumer typically requires a regasified gas having a temperature of about 0°C to about 10°C or about 8°C to 10°C and a pressure of 50 bar to 100 bar, the trim heater 130 may heat the regasified gas to be supplied from the vaporizer 120 to the onshore gas consumer to a temperature of about 0°C to 10°C.

[67] According to this embodiment, LNG stored in the LNG storage tank is compressed by the high-pressure pump 110, gasified by the vaporizer 120, and heated by the trim heater 130 to be supplied to the gas consumer while flowing along a liquefied gas line LL.

[68] According to this embodiment, the first cycle includes a first pump 210 adapted to circulate the first heating medium, a first heat exchanger 220 adapted to gasify the first heating medium compressed by the first pump 210, an expander-generator 230 adapted to expand the first heating medium gasified by the first heat exchanger 220 and to generate power through conversion of expansion of the first heating medium into power, and a receiver 240 adapted to store the first heating medium condensed through heat exchange with LNG in the vaporizer 120.

[69] The first heating medium circulates in the first cycle corresponding to a loop cycle in which the first heating medium is compressed by the first pump 210, gasified by the first heat exchanger 220, expanded by the expander-generator 230, condensed by the vaporizer 120, and supplied to the first pump 210 through the receiver 240 while flowing along a first heating medium line RL.

[70] In the first heat exchanger 220 according to this embodiment, the first heating medium is suctioned by a seawater pump 410 and is gasified through heat exchange with seawater supplied to the first heat exchanger 220 along a first seawater line SL1.

[71] In the first heat exchanger 220, seawater is cooled while gasifying the first heating medium and the cooled seawater may be discharged from the first heat exchanger 220 along the first seawater line SL1.

[72] In this embodiment, seawater is used as a heat source for gasification of the

first heating medium in the first heat exchanger 220 by way of example. However, it should be understood that steam generated in an on-board steam generator (not shown) may be used alone or complementarily together with seawater.

[73] For example, for complementary use of seawater and steam, the first heat exchanger 220 may include a 3-stage stream heat exchanger in which heat exchange of the first heating medium with seawater and steam occurs. Alternatively, a first stage heat exchanger adapted to perform heat exchange between the first heating medium and seawater and a second stage heat exchanger adapted to perform heat exchange between the first heating medium and steam may be disposed in series such that the first heating medium can be heated stepwise, or the first stage heat exchanger adapted to perform heat exchange between the first heating medium and seawater and the second stage heat exchanger adapted to perform heat exchange between the first heating medium and steam may be disposed in parallel to regulate the temperature of the first heating medium heated by the first heat exchanger 220. Alternatively, the liquefied gas regasification system may further include a seawater heater adapted to heat seawater through heat exchange with steam to supply the seawater heated by the seawater heater to the first heat exchanger 220.

[74] Further, the first heat exchanger 220 according to this embodiment may be a shell & tube heat exchanger or a plate-type heat exchanger.

[75] The first heating medium gasified or heated by seawater in the first heat exchanger 220 is supplied to the expander-generator 230 in which the first heating medium is expanded and expansion of the first heating medium is converted into power. Power generated by the expander-generator 230 may be used by an on-board power consumer.

[76] According to this embodiment, the first heating medium line RL includes a first branch-off line RL1, which is branched off upstream of the expander-generator 230 and is connected to the vaporizer 120 such that the first heating medium gasified by the first heat exchanger 220 can be directly supplied from the first heat exchanger 220 to the vaporizer 120 after bypassing the expander-generator 230, that is, without passing through the expander-generator 230.

[77] When the expander-generator 230 cannot be used due to failure thereof, the

first heating medium is supplied from the first heat exchanger 220 to the vaporizer 120 through the first branch-off line RL1, thereby preventing an influence on supply of natural gas to an onshore gas consumer.

[78] Further, the first branch-off line RL1 serves to allow the first heating medium to bypass the expander-generator 230 upon maintenance of the expander-generator 230 and to regulate an upstream pressure corresponding to retardation of the response rate at an inlet side valve of the expander-generator 230 upon increase in a circulation flow rate of the first heating medium due to rapid increase in regasification capacity of the vaporizer 120.

[79] In the expander-generator 230, the first heating medium vaporized or heated through heat exchange with seawater in the first heat exchanger 220 may be reduced in pressure and temperature while expanding.

[80] The first heating medium expanded in the expander-generator 230 is supplied to the vaporizer 120 along the first heating medium line RL to be cooled or condensed through heat exchange with LNG in the vaporizer 120. The first heating medium cooled or condensed in the vaporizer 120 is delivered to the receiver 240 along the first heating medium line RL.

[81] The receiver 240 according to this embodiment is a pressure vessel to which the first heating medium condensed by the vaporizer 120 is supplied, and also acts as a buffering tank by controlling the flow rate and pressure of the first heating medium circulated in the first cycle. The pressure of the receiver 240 may be maintained at a constant pressure through control of a second valve RV described below.

[82] In this embodiment, the first heating medium may be selected from materials or mixtures thereof undergoing phase change while circulating in the first cycle.

[83] That is, the first heating medium may be gasified through heat exchange with seawater in the first heat exchanger 220, expanded in the expander-generator 230, and condensed in the vaporizer 120.

[84] According to this embodiment, the first heating medium may be a natural refrigerant, a hydrofluorocarbon (HFC) based refrigerant, a hydrofluoroolefin (HFO)

based refrigerant, or a mixture thereof not providing fire and explosion risks. For example, the first heating medium may be R-23, R-32, R-134a, R-407c, R-410A, or a mixture thereof.

[85] In the expander-generator 230, the first heating medium isentropically expands and undergoes decrease in temperature in this process.

[86] For example, when the first heating medium gasified and heated in the first heat exchanger 220 has a temperature of 11°C and a pressure of 5 barg and is expanded to a pressure of 2 barg in the expander-generator 230, the temperature of the first heating medium is decreased to about -10.5°C. When the first heating medium discharged from the expander-generator 230 and having a temperature of -10.5°C is supplied as a heat source for gasification of LNG in the vaporizer 120, natural gas discharged from the vaporizer 120 cannot satisfy the lowest temperature condition, for example, a temperature of 8°C.

[87] Thus, according to the embodiment, the regasification system further includes the trim heater 130 that heats the natural gas supplied from the vaporizer 120 to a gas consumer to a temperature higher than or equal to the lowest temperature condition required for the gas consumer.

[88] As such, according to the embodiment, the first heating medium gasified by the first heat exchanger 220 is reduced in temperature while generating power in the expander-generator 230. As a result, since the temperature of the first heating medium supplied to the vaporizer 120 is lower than a temperature required for heating the regasified gas to a temperature required for the gas consumer, it is possible to solve this problem using the trim heater 130 disposed downstream of the vaporizer 120.

[89] In this embodiment, as power is generated by the first heating medium in the expander-generator 230, it is possible to reduce load of a power generation engine provided to the regasification vessel while reducing fuel consumption.

[90] According to this embodiment, the regasification system may further include a second cycle in which the second heating medium is circulated as a heat source for heating natural gas in the trim heater 130.

[91] In the trim heater 130, the natural gas is subjected to heat exchange with the

second heating medium circulating in the second cycle, whereby the natural gas is heated to a temperature higher than or equal to the lowest temperature condition, that is, a temperature required for the gas consumer, and the second heating medium is cooled or condensed by recovering cold heat of the natural gas.

[92] The second cycle according to this embodiment includes a second pump 310 adapted to circulate a second heating medium, a second heat exchanger 320 adapted to heat or gasify the second heating medium, and an expansion tank 330 adapted to stabilize the second heating medium discharged from the trim heater 130 after heat exchange.

[93] The second heating medium circulates in the second cycle corresponding to a loop cycle in which the second heating medium is compressed by the second pump 310, gasified or heated by the second heat exchanger 320, cooled or condensed in the trim heater 130, and supplied to the second pump 310 through the expansion tank 330 while flowing along a second heating medium line GL.

[94] In the second heat exchanger 320 according to this embodiment, a heat source for heating the second heating medium may be seawater suctioned by the seawater pump 410 and supplied to the second heat exchanger 320 along a second seawater line SL2.

[95] In the second heat exchanger 320, seawater is cooled while gasifying or heating the second heating medium and the cooled seawater may be discharged from the second heat exchanger 320 along the second seawater line SL2.

[96] In this embodiment, seawater is used as a heat source for gasifying or heating the second heating medium in the second heat exchanger 320 by way of example. However, it should be understood that steam generated in an on-board steam generator may be used alone or complementarily together with seawater, as in the first heat exchanger 220.

[97] Further, the second heat exchanger 320 according to this embodiment may be a plate-type heat exchanger.

[98] The expansion tank 330 according to this embodiment may act as a buffering tank corresponding to volume expansion resulting from variation in temperature of the second heating medium through heat exchange in the second heat

exchanger 320.

[99] Further, in the expansion tank 330, foreign matter, such as air and the like, which enters the second heating medium, may be separated from the second heating medium, and, when the natural gas is leaked from the trim heater 130 and flows into the second heating medium, the gas having flown into the second heating medium may also be removed from the second heating medium.

[100] In this embodiment, the second heating medium may be glycol water.

[101] In the expander-generator 230, the first heating medium gasified or heated through heat exchange with seawater in the first heat exchanger 220 is reduced in pressure and temperature while expanding.

[102] Except for the case where the temperature of the seawater used as a heat source in the first heat exchanger 220 is sufficiently higher than the lowest temperature condition for the gas consumer, it is difficult to heat the natural gas above the lowest temperature condition since the first heating medium undergoes very significant decrease in temperature due to variation in pressure of the first heating medium in the expander-generator 230 and has low heat capacity.

[103] Thus, according to this embodiment, the second heating medium, that is, glycol water, may be used as an intermediate heat medium for heating natural gas above the lowest temperature condition.

[104] In general, LNG is compressed above the lowest pressure condition in the high-pressure pump 110 and is vaporized and heated above the lowest temperature condition in the vaporizer 120. For example, when the lowest temperature condition of the natural gas discharged from the vaporizer 120 is 8°C, the first heating medium supplied to the vaporizer 120 is required to have a higher temperature than 8°C in order to satisfy this condition. Considering that the minimum temperature difference between a heating fluid and a fluid to be heated in a general heat exchanger ranges from 2°C to 3°C, the temperature of the first heating medium supplied to the vaporizer 120 is about 11°C or higher.

[105] In this embodiment, since the first heating medium is heated by heat exchange with seawater in the first heat exchanger 220, the temperature of seawater supplied to the first heat exchanger 220 is about 14°C or more, considering the

minimum temperature difference between the heating fluid and the fluid to be heated in the general heat exchanger.

[106] However, even when the first heating medium is heated to 11°C in the first heat exchanger 220, the temperature of the first heating medium may be lowered to -10.5°C while generating power in the expander-generator 230, as described above.

[107] Thus, according to this embodiment, the trim heater 130 is used to heat the natural gas vaporized in the vaporizer 120 to the lowest temperature condition for the gas consumer, that is, a final delivery temperature of the natural gas.

[108] If some of the first heating medium supplied from the first heat exchanger 220 to the expander-generator 230 is branched and used as a heating medium for heating the natural gas in the trim heater 130, there can be a problem that the natural gas cannot be heated to the final delivery temperature due to insufficient heat exchange in the trim heater 130, except when the temperature of seawater is sufficiently high such that the temperature difference between the first heating medium and the seawater performing heat exchange in the first heat exchanger 220 becomes higher than the minimum level.

[109] Referring to FIG. 3, since a pinch point is determined inside the trim heater 130 due to low heat capacity and phase change of the first heating medium, the design of the trim heater 130 is not easy. Thus, such difficulty in design can be solved and the regasified gas can be stably heated using the second heating medium.

[110] However, according to this embodiment, the first heating medium, that is, the refrigerant, is used only as the heat source of the vaporizer 120 through heat exchange with the seawater in the first heat exchanger 220 and the second heating medium, that is, glycol water, heated through heat exchange with the seawater in the second heat exchanger 320 is supplied as the heat source of the trim heater 130 to prevent generation of the pinch point inside the trim heater 130 (see FIG. 4), thereby securing sufficient heat exchange performance while stably heating the natural gas to the final delivery temperature.

[111] Further, in an initial operation stage of the regasification system, when LNG is not supplied to the vaporizer 120, the first heating medium is not condensed in the vaporizer 120 and thus cannot be circulated. Thus, it is necessary to increase

load of the vaporizer 120 while maintaining supply balance between LNG and the first heating medium. This causes difficulty in operation of the liquefied-gas regasification system.

[112] However, according to this embodiment, glycol water is used as the second heating medium for heating the natural gas in the trim heater 130, whereby the regasification system can prevent LNG from entering the vaporizer 120 due to supply unbalance between LNG and the first heating medium in an initial operation stage of the regasification system, thereby enabling stable operation of the regasification system.

[113] Further, according to this embodiment, as shown in FIG. 1 and FIG. 2, the seawater pump 410, the first heat exchanger 220 and the second heat exchanger 320 are disposed in a machinery space under the deck, and the vaporizer 120 and the trim heater 130 are disposed on an upper deck.

[114] When the seawater suctioned by the seawater pump 410 disposed under the deck is directly supplied to the vaporizer 120 and the trim heater 130 disposed on the upper deck, that is, upon direct heat exchange between the seawater and LNG, the seawater pump 410 suffers from significant power consumption.

[115] However, as in this embodiment, the first cycle is provided to allow heat exchange between the seawater suctioned by the seawater pump 410 and the first heating medium in the first heat exchanger 220 disposed in the machinery space under the deck such that LNG is gasified in the vaporizer 120 by the first heating medium heated by the seawater, and the second cycle is provided to allow heat exchange between the seawater and the second heating medium in the second heat exchanger 320 disposed in the machinery space under the deck such that natural gas is heated in the trim heater 130 by the second heating medium heated by the seawater, thereby reducing power consumption through reduction in minimum head of the seawater pump 410.

[116] Here, despite power consumption of the first pump 210 and/or the second pump 310 for circulation of the first heating medium and/or the second heating medium, the overall power consumption is reduced since the circulation amounts thereof are not large, as compared with the circulation amount of the seawater.

[117] Upon regasification of LNG through indirect heat exchange with seawater using glycol water, power reduction is about 30% and is about 45% in use of the combination of the first cycle and the second cycle, as compared with the case where LNG is regasified through direct heat exchange of LNG with the seawater.

[118] Next, a temperature control method of the regasification system according to the embodiment of the invention will be described with reference to FIG. 2. FIG. 2 is a schematic diagram of the liquefied gas regasification system shown in FIG. 1, illustrating a temperature controller for description of the temperature control method, in which some components of the regasification system are omitted.

[119] Referring to FIG. 2, the regasification system according to this embodiment further includes a second pressure measurement unit PT2 adapted to measure an inner pressure of the receiver 240 and a second branch-off line RL2 branched upward of the vaporizer 120 from the first heating medium line RL and connected to the receiver 240, in which a second valve RV is provided to the second branch-off line RL2.

[120] In addition, the regasification system according to this embodiment further includes a second pressure controller PIC2 that controls the second valve RV in order to regulate the flow rate of the first heating medium bypassing the vaporizer 120 and supplied to the receiver 240 among the first heating medium supplied from the expander-generator 230 and/or the first heat exchanger 220 to the vaporizer 120 depending upon the pressure measured by the second pressure measurement unit PT2.

[121] The second valve RV may also be controlled depending upon the temperature of the natural gas measured by a third temperature controller TIC3 that measures the temperature of the natural gas supplied from the vaporizer 120 to the trim heater 130.

[122] The second controller LS2 may control the opening degree of the second valve RV based on the flow rate of the first heating medium branched off toward the second branch-off line RL2, in order to maintain the flow rate of the first heating medium branched off towards the second branch-off line RL2, as sent from the second pressure controller PIC2, and to maintain the temperature of the natural gas

supplied from the vaporizer 120 to the trim heater 130, as sent from the third temperature controller TIC3.

[123] According to this embodiment, the second controller LS2 may include a low selector adapted to control the second valve RV by selecting a smaller value among the opening degrees of the second valve RV for controlling the flow rate of the first heating medium to be branched off towards the second branch-off line RL2, as sent from the second pressure controller PIC2 and the third temperature controller TIC3.

[124] For example, when the pressure of the receiver 240 measured by the second pressure measurement unit PT2 is lower than a predetermined value, the second pressure controller PIC2 sends a signal to the second controller LS2 so as to increase the flow rate of the first heating medium, which bypasses the vaporizer 120 to be supplied to the receiver 240, by increasing the opening degree of the second valve RV.

[125] In addition, when the temperature of the natural gas supplied from the vaporizer 120 to the trim heater 130 is lower than a predetermined value, the third temperature controller TIC3 sends a signal to the second controller LS2 so as to decrease the flow rate of the first heating medium, which bypasses the vaporizer 120, by decreasing the opening degree of the second valve RV.

[126] Here, the second controller LS2 controls the opening degree of the second valve RV by selecting a smaller value among the opening degrees of the second valve RV, as sent from the second pressure controller PIC2 and the third temperature controller TIC3. That is, the second controller LS2 controls the opening degree of the second valve RV while maintaining the minimum flow rate of the first heating medium to be regulated to bypass the vaporizer 120.

[127] Further, the regasification system according to this embodiment includes a first temperature measurement unit TT1 adapted to measure the temperature of the natural gas supplied from the trim heater 130 to a gas consumer, a first pressure measurement unit PT1 adapted to measure the pressure of the natural gas supplied from the trim heater 130 to the gas consumer, and a first flow rate measurement unit FT1 adapted to measure the flow rate of the natural gas supplied from the trim heater

130 to the gas consumer.

[128] In addition, the regasification system according to this embodiment further includes a first temperature controller TIC1 adapted to maintain the temperature of the natural gas supplied from the trim heater 130 to the gas consumer depending upon the temperature measured by the first temperature measurement unit TT1, and a first flow rate controller FIC1 adapted to regulate the flow rate of the natural gas supplied from the trim heater 130 to the gas consumer depending upon the values measured by the first temperature measurement unit TT1, the first pressure measurement unit PT1 and the first flow rate measurement unit FT1.

[129] In addition, the regasification system according to this embodiment further includes a second temperature measurement unit TT2 adapted to measure the temperature of the second heating medium discharged from the trim heater 130 and a second temperature controller TIC2 adapted to maintain the temperature of the second heating medium discharged from the trim heater 130 depending upon the temperature measured by the second temperature measurement unit TT2.

[130] In addition, the regasification system according to this embodiment further includes a first valve V provided to a liquefied gas line LL along which LNG supplied from the high-pressure pump 110 to the vaporizer 120 flows.

[131] The first controller LS1 may regulate the opening degree of the first valve V in response to signals sent from the first temperature controller TIC1, the second temperature controller TIC2, and the first flow rate controller FIC1.

[132] For example, when the flow rate measured by the first flow rate measurement unit FT1 is less than a value required for the gas consumer, the first controller LS1 may satisfy a target regasification amount by increasing the opening degree of the first valve V in response to the signal sent from the first flow rate controller FIC1 so as to increase the flow rate of LNG supplied from the high-pressure pump 110 to the vaporizer 120.

[133] In addition, for example, when the temperature measured by the first temperature measurement unit TT1 does not satisfy the lowest temperature condition, the first controller LS1 may satisfy a target regasification temperature by decreasing the opening degree of the first valve V in response to the signal sent from the first

temperature controller TIC1 so as to decrease the flow rate of LNG supplied from the high-pressure pump 110 to the vaporizer 120.

[134] Further, for example, when the temperature measured by the second temperature measurement unit TT2 approaches a predetermined value, the first controller LS1 may maintain the temperature of the second heating medium at an outlet of the trim heater 130 to be higher than or equal to the minimum temperature by decreasing the opening degree of the first valve V in response to the signal sent from the second temperature controller TIC so as to decrease the flow rate of LNG supplied from the high-pressure pump 110 to the vaporizer 120.

[135] According to this embodiment, the first controller LS1 may include a low selector adapted to control the opening degree of the first valve V by selecting the lowest value of the first valve LV, that is, the lowest opening degree thereof, among the signals sent from the first flow rate controller FIC1, the first temperature controller TIC1 and the second temperature controller TIC2.

[136]

[137] As described above, the regasification system according to the present invention can generate power while reducing fuel consumption for power generation by recovering cold heat discarded in regasification of liquefied gas, and can maintain a delivery temperature, pressure and flow rate of the regasified gas within predetermined ranges even upon reduction in temperature of a heat source supplied to the vaporizer by additionally generating power through recovery of the cold heat of the liquefied gas.

[138] Although some embodiments have been described herein, it should be understood by those skilled in the art that various modifications, variations, and alterations can be made by those skilled in the art without departing from the spirit and scope of the present invention. Therefore, it should be understood that the above embodiments are given by way of illustration only and the present invention is not intended to be unduly limited thereby. The scope of the present invention should be defined by the appended claims and equivalents thereto.

[139] <List of Reference Numerals>

110: High-pressure pump

120: Vaporizer

130: Trim heater
 210: First pump 310: Second pump
 220: First heat exchanger 320: Second heat exchanger
 230: Expander-generator 330: Expansion tank
 240: Receiver 410: Seawater pump
 LL: Liquefied gas line
 RL: First heating medium line
 RL1: First branch-off line RL2: Second branch-off line
 GL: Second heating medium line
 SL1: First seawater line SL2: Second seawater line
 LV: First valve RV: Second valve
 TT1: First temperature measurement unit
 TT2: Second temperature measurement unit
 PT1: Second pressure measurement unit
 PT2: Second pressure measurement unit
 FT1: First flow rate measurement unit
 TIC1: First temperature controller TIC2: Second temperature controller
 TIC3: Third temperature controller
 PIC2: Second pressure controller FIC1: First flow rate controller
 LS1: First controller LS2: Second controller.

【CLAIMS】**【Claim 1】**

A liquefied-gas regasification system for vessels, comprising:

- a high-pressure pump pressurizing the liquefied gas to a pressure range required for the gas consumer;
- a vaporizer gasifying liquefied gas pressurized using the high-pressure pump into a regasified gas through heat exchange with a first heating medium;
- a trim heater heating the regasified gas to a temperature required for a gas consumer through heat exchange with a second heating medium when the regasified gas is delivered from the vaporizer to the gas consumer;
- a first heat exchanger gasifying the first heating medium condensed by heat exchanging with the liquefied gas in the vaporizer through heat exchange with a heat source;
- an expander-generator generating power through expansion of the first heating medium gasified by the first heat exchanger;
- a first heating medium line delivering the first heating medium expanded using the expander-generator to the vaporizer, and
- a second heat exchanger heating the second heating medium to be supplied to the trim heater through heat exchange with a heat source,

wherein the first heating medium is undergoing phase change while circulating through the vaporizer and the first heat exchanger, and the second heating medium is not undergoing change while circulating through the trim heater and the second heat exchanger.

【Claim 2】

The liquefied gas regasification system according to claim 1, wherein the heat source comprises one of seawater and steam.

【Claim 3】

The liquefied gas regasification system according to claim 1, wherein the first heating medium is a refrigerant undergoing phase change while circulating in a first cycle and is selected from among a natural refrigerant, an HFO-based refrigerant, an HFC-based refrigerant, and a mixture thereof.

【Claim 4】

The liquefied gas regasification system according to claim 1, further comprising:

a first branch-off line branched off upstream of the expander-generator from a first heating medium line connected to the expander-generator to deliver the first heating medium gasified by the first heat exchanger to the expander-generator,

the first branch-off line being connected to the vaporizer such that the first heating medium supplied to the expander-generator is supplied to the vaporizer after bypassing the expander-generator along the first branch-off line.

【Claim 5】

The liquefied gas regasification system according to claim 1, further comprising:

a first valve controlling a flow rate of the liquefied gas supplied from the high-pressure pump to the vaporizer.

【Claim 6】

The liquefied gas regasification system according to claim 1, further comprising:

a receiver receiving the first heating medium condensed in the course of gasifying the liquefied gas in the vaporizer;

a second branch-off line branched off upstream of the vaporizer from the first heating medium line delivering the first heating medium to the vaporizer such that the

first heating medium is supplied to the receiver after bypassing the vaporizer along the second branch-off line;

a second valve disposed on the second branch-off line; and

a second controller regulating an opening degree of the second valve to maintain the internal pressure of the receiver.

【Claim 7】

A liquefied-gas regasification method for vessels, comprising:

pressurizing the liquefied-gas to a pressure range required for the gas consumer;

gasifying the pressurized liquefied gas through heat exchange with a first heating medium; and

heating the regasified gas by heat exchanging with the first heating medium to a temperature required for a gas consumer through heat exchange with a second heating medium,

gasifying the first heating medium condensed by heat exchanging with the liquefied gas through heat exchange with a heat source,

expanding the gasified first heating medium using an expander-generator to generate power and subjected to heat exchange with the liquefied gas,

wherein the first heating medium circulates in a closed cycle while heat exchanging with the liquefied gas and the heat source and undergoes phase change while circulating the closed cycle, and the second heating medium circulates in a closed cycle while heat exchanging with the regasified gas and the heat source and does not undergo change while circulating through the closed cycle.

【Claim 8】

The liquefied-gas regasification method for vessels according to claim 7, wherein:

a heat source for heating the first heating medium and the second heating medium is seawater or steam.

【Claim 9】

The liquefied-gas regasification method for vessels according to claim 7, wherein:

controlling a flow rate of the first heating medium gasified by heat exchanging with the heat source to divide a flow rate supplying to the expander-generator and a flow rate bypassing the expander-generator;

wherein the flow rate bypassing the expander-generator is heat exchanging with the liquefied gas without expand.

【Claim 10】

The liquefied-gas regasification method for vessels according to claim 7, wherein:

controlling a flow rate of the expanded first heating medium to divide a flow rate to heat exchanging with the liquefied gas and a flow rate to heat exchanging with the heat source without heat exchanging with the liquefied gas,

wherein a pressure of the closed cycle circulated the first heating medium is maintaining by the controlling the flow rate of the expanded first heating medium.