(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 230 513 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
23.08.2023 Bulletin 2023/34

(21) Application number: **20957834.3**

(22) Date of filing: **21.12.2020**

(51) International Patent Classification (IPC):
B63B 25/16 *(2006.01)* ***B63J 3/04*** *(2006.01)*
F17C 9/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B63B 25/16; B63J 3/04; F17C 9/00

(86) International application number:
PCT/KR2020/018810

(87) International publication number:
WO 2022/080590 (21.04.2022 Gazette 2022/16)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **14.10.2020 KR 20200132686**
14.10.2020 KR 20200132687

(71) Applicant: **Daewoo Shipbuilding & Marine Engineering Co., Ltd.**
Geoje-si, Gyeongsangnam-do 53302 (KR)

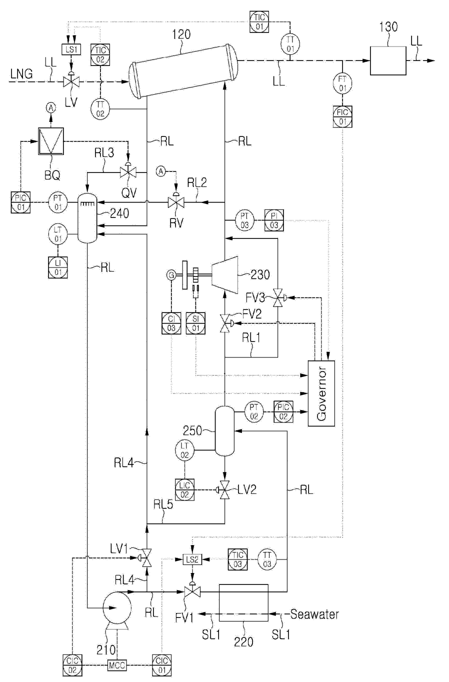
(72) Inventors:
- **AN, Su Kyung**
  Gwangmyeong-si, Gyeonggi-do 14243 (KR)
- **CHO, Du Hyeon**
  Siheung-si, Gyeonggi-do 15010 (KR)
- **WON, Dae Han**
  Goyang-si, Gyeonggi-do 10361 (KR)
- **BYUN, Young Jin**
  Seoul 07712 (KR)
- **SEO, Da Hye**
  Incheon 22785 (KR)

(74) Representative: **Cabinet Beau de Loménie**
158, rue de l'Université
75340 Paris Cedex 07 (FR)

(54) METHOD AND SYSTEM FOR RE-GASIFYING LIQUEFIED GAS OF SHIP

(57) The present invention relates to a liquefied-gas regasification system and method for vessels, which enable stable operation of a cycle, in which a heating medium for heat exchange with a liquefied gas circulates, by maintaining operation conditions for regasification of the liquefied gas at a main point of the cycle. The liquefied-gas regasification method includes gasifying a first heating medium condensed into a liquid phase through heat exchange in a vaporizer; supplying the gasified first heating medium to an expander-generator to generate power through expansion of the gasified first heating medium, and supplying the expanded first heating medium to the vaporizer while controlling a pressure upstream or downstream of the expander-generator to control a pressure downstream of the vaporizer.

【FIG. 1】



EP 4 230 513 A1

Description

[Technical Field]

[0001] The present invention relates to a liquefied-gas regasification system and method for vessels, which enable stable operation of a cycle, in which a heating medium for heat exchange with a liquefied gas circulates, by maintaining operation conditions for regasification of the liquefied gas at a main point of the cycle.

[Background Art]

[0002] 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.

[0003] 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.

[0004] 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.

[0005] 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.

[0006] For easy supply, seawater is mainly used as a heat source for gasification of LNG in the vaporizer. 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 LNG, the cold heat of LNG recovered by the seawater is discarded to sea as is.

[0007] LNG has a cold-heat energy of 200 kcal/kg. Thus, in the process of regasifying LNG, the cold heat of LNG recovered by the seawater is discarded from an LNG regasification vessel instead of being effectively used.

[Disclosure]

[Technical Problem]

[0008] Embodiments of the present invention provide a liquefied-gas regasification system and method for vessels, which can improve energy efficiency by generating power through recovery of cold heat discarded in regasification of liquefied gas and enable stable operation through pressure regulation.

[Technical Solution]

[0009] In accordance with one aspect of the present invention, there is provided a liquefied-gas regasification method of a vessel, including: gasifying liquefied gas through heat exchange with a first heating medium in a vaporizer; and recovering cold heat from the first heating medium discharged from the vaporizer to recirculate the cold heat to the vaporizer, wherein recovering the cold heat from the first heating medium includes: gasifying the first heating medium in a first heat exchanger, the first heating medium being condensed into a liquid phase through heat exchange in the vaporizer; supplying the gasified first heating medium to an expander-generator to generate power through expansion of the gasified first heating medium, and supplying the expanded first heating medium to the vaporizer while controlling a pressure upstream or downstream of the expander-generator to control a pressure downstream of the vaporizer.

[0010] In accordance with another aspect of the present invention, there is provided a liquefied-gas regasification system of a vessel, including: a vaporizer gasifying liquefied gas through heat exchange with a first heating medium; a first heat exchanger gasifying the first heating medium condensed into a liquid phase by heat exchange in the vaporizer; an expander-generator expanding the first heating medium gasified in the first heat exchanger to generate power; and a pressure controller controlling a pressure upstream or downstream of the expander-generator, wherein a pressure downstream of the vaporizer is controlled by controlling the pressure upstream or downstream of the expander-generator.

[0011] In accordance with a further aspect of the present invention, there is provided a liquefied-gas regasification method of a vessel, including: gasifying liquefied gas through heat exchange with a first heating medium in a vaporizer;

and recovering cold heat from the first heating medium discharged from the vaporizer to recirculate the cold heat to the vaporizer, wherein recovering the cold heat from the first heating medium includes: gasifying the first heating medium in a first heat exchanger, the first heating medium being condensed into a liquid phase by heat exchange in the vaporizer; supplying the gasified first heating medium to an expander-generator to generate power through expansion of the gasified first heating medium; and supplying the expanded first heating medium to the vaporizer, wherein a receiver receives the first heating medium discharged from the vaporizer and the first heating medium discharged from the receiver is gasified in order to control a pressure downstream of the expander-generator, and wherein, when a pressure measurement value of the receiver is less than a preset value, a liquefied-gas regasification system is operated in a bypass mode in which the first heating medium expanded in the expander-generator and having a high temperature is supplied to the receiver after bypassing the vaporizer, and, when the pressure measurement value of the receiver is greater than a preset value, the liquefied-gas regasification system is operated in a quenching mode in which the first heating medium discharged from the vaporizer and having a low temperature is supplied into the receiver through a spray nozzle disposed at an upper end of the receiver.

[0012] The first heating medium may undergo phase change through heat exchange in the vaporizer and the first heat exchanger.

[0013] A flow rate of the liquefied gas supplied to the vaporizer may be regulated to maintain a preset temperature of the first heating medium having a low temperature and discharged from the vaporizer after heat exchange and a preset temperature of the regasified gas discharged from the vaporizer after heat exchange.

[0014] The flow rate of the liquefied gas supplied to the vaporizer may be regulated based on a smaller value among an output value for maintaining a preset temperature of the first heating medium having a low temperature and discharged from the vaporizer after heat exchange and an output value for maintaining a preset temperature of the regasified gas discharged from the vaporizer after heat exchange.

[0015] The preset temperature of the first heating medium may be a saturation temperature of the first heating medium and the pressure downstream of the expander-generator may be controlled by changing the preset temperature of the first heating medium depending upon a saturation pressure of the first heating medium.

[0016] The regasified gas gasified in the vaporizer may be heated to a temperature required for a gas consumer through heat exchange with a second heating medium in a trim heater.

[0017] When the pressure downstream of the expander-generator is less than a preset value or a power generation load is low, the first heating medium having a gas phase may be regulated to flow downstream of the expander-generator after bypassing the expander-generator.

[0018] In accordance with still another aspect of the present invention, there is provided a liquefied-gas regasification system of a vessel, including: a vaporizer gasifying liquefied gas through heat exchange with a first heating medium; a receiver receiving the first heating medium having a low temperature and discharged from the vaporizer after heat exchange; a first heat exchanger gasifying the first heating medium supplied from the receiver and having a liquid phase; an expander-generator expanding the first heating medium gasified in the first heat exchanger to generate power; a first heating medium line along which the first heating medium expanded by the expander-generator is delivered from the expander-generator to the vaporizer and the first heating medium recovering cold heat of the liquefied gas is delivered from the vaporizer to the receiver; a second valve disposed downstream of the expander-generator to allow the first heating medium to flow to the receiver after bypassing the vaporizer; a third valve allowing the first heating medium discharged from the vaporizer to be supplied into the receiver through a spray nozzle disposed at an upper end of the receiver; and a second controller opening the second valve when a pressure measurement value of the receiver is less than a preset value and opening the third valve when the pressure measurement value of the receiver is greater than a preset value.

[0019] The liquefied-gas regasification system may further include: a first valve regulating a flow rate of the liquefied gas supplied to the vaporizer; and a first controller controlling the first valve to maintain a preset temperature of the first heating medium having a low temperature and discharged from the vaporizer after heat exchange and to maintain a preset temperature of the regasified gas discharged from the vaporizer after heat exchange.

[0020] The preset temperature of the first heating medium may be a saturation temperature of the first heating medium and the liquefied-gas regasification system may further include a third controller adjusting the preset temperature of the first heating medium depending upon the pressure measurement value of the receiver.

[0021] The liquefied-gas regasification system may further include a trim heater additionally heating the regasified gas gasified in the vaporizer to a temperature required for a gas consumer.

[0022] The liquefied-gas regasification system may further include a second cycle in which a second heating media recovering cold heat of the regasified gas through heat exchange with the regasified gas in the trim heater is circulated.

[0023] The liquefied-gas regasification system may further include: a third flow rate valve allowing the first heating medium gasified in the first heat exchanger to flow downstream of the expander-generator after bypassing the expander-generator; and a governor controlling the third flow rate valve depending upon a pressure downstream of the expander-generator and a power generation load of the expander-generator.

[0024] The vaporizer may be a 1-pass type shell & tube heat exchanger.

[0025] The trim heater may be a 2-pass type shell & tube heat exchanger.

[0026] In accordance with still another aspect of the present invention, there is provided a liquefied-gas regasification method of a vessel, including: gasifying liquefied gas through heat exchange with a first heating medium in a vaporizer; and recovering cold heat from the first heating medium discharged from the vaporizer to recirculate the cold heat to the vaporizer, wherein recovering the cold heat from the first heating medium includes: gasifying the first heating medium in a first heat exchanger, the first heating medium being condensed into a liquid phase by heat exchange in the vaporizer; supplying the gasified first heating medium to an expander-generator to generate power through expansion of the gasified first heating medium; and supplying the expanded first heating medium to the vaporizer, and wherein a knock-out drum receives the first heating medium gasified in the first heat exchanger before the gasified first heating medium is supplied to the expander-generator, and, when a pressure measurement value of the knock-out drum is greater than a preset value, a pressure upstream of the expander-generator is controlled by increasing an output of the expander-generator.

[0027] Increasing the output of the expander-generator may increase an open degree of a second flow rate valve allowing the first heating medium to flow from the knock-out drum to the expander-generator and may be performed corresponding to the opening degree of the second flow rate valve.

[0028] A rotational speed of the expander-generator may be controlled by a sixth controller and the opening degree of the second flow rate valve may be regulated by the sixth controller in response to a control signal sent from a fifth controller depending upon the pressure measurement value.

[0029] When the opening degree of the second flow rate valve reaches a maximum degree or the output of the expander-generator reaches a maximum output, the fifth controller may open a third flow rate valve to allow the first heating medium to flow downstream of the expander-generator from the knock-out drum after bypassing the expander-generator.

[0030] Increasing the output of the expander-generator may include opening the third flow rate valve to allow the first heating medium to flow downstream of the expander-generator from the knock-out drum after bypassing the expander-generator, increasing the output of the expander-generator within an allowable output range of the expander-generator while decreasing the opening degree of the third flow rate valve, and increasing the opening degree of the second flow rate valve to allow the first heating medium to flow from the knock-out drum to the expander-generator.

[0031] The rotational speed of the expander-generator may be controlled by a sixth controller and a seventh controller managing a variation of the third flow rate valve may send a signal to the sixth controller to increase the rotational speed of the expander-generator until the opening degree of the third flow rate valve reaches 0%.

[0032] A circulation flow rate of the first heating medium may be determined based on a heating duty of the vaporizer.

[0033] In accordance with still another aspect of the present invention, there is provided a liquefied-gas regasification system of a vessel, including: a vaporizer gasifying liquefied gas through heat exchange with a first heating medium; a first heat exchanger gasifying the first heating medium condensed into a liquid phase by heat exchange in the vaporizer; an expander-generator expanding the first heating medium gasified in the first heat exchanger to generate power; a knock-out drum receiving the first heating medium gasified in the vaporizer; a second flow rate valve allowing the first heating medium discharged in a gas phase from the knock-out drum to be supplied to the expander-generator through regulation of an opening degree thereof; a third flow rate valve allowing the first heating medium discharged in a gas phase from the knock-out drum to bypass the expander-generator through regulation of an opening degree thereof; and a sixth controller controlling an output of the expander-generator depending upon a pressure of the knock-out drum and regulating the opening degree of the second flow rate valve depending upon the output of the expander-generator to control a pressure upstream of the expander-generator.

[0034] The liquefied-gas regasification system may further include: a fifth controller sending a signal for increasing the output of the expander-generator to the sixth controller depending upon the pressure measurement value of the knock-out drum and opening the third flow rate valve when the output of the expander-generator reaches a maximum output.

[0035] The liquefied-gas regasification system may further include: a pressure controller opening the third flow rate valve when the pressure measurement value of the knock-out drum is greater than a preset value; and a seventh controller sending a signal for increasing a rotational speed of the expander-generator to the sixth controller until the opening degree of the third flow rate valve reaches a minimum value.

[Advantageous Effects]

[0036] 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.

[0037] In addition, a pressure downstream of a vaporizer may be controlled through regulation of the pressure of a receiver, thereby improving responsiveness in regulation of the temperature of a first heating medium and the flow rate of the liquefied gas to be gasified for controlling the pressure downstream of the vaporizer.

[0038] Further, an inlet-side (high pressure-side) pressure of an expander-generator may be controlled, thereby improving responsiveness in regulation of the temperature of the first heating medium and the flow rate of the liquefied gas to be gasified for controlling the pressure downstream of the vaporizer.

[0039] Further, power can be generated using the first heating medium, thereby allowing stable supply of the regasified gas to a gas consumer after being heated to the minimum delivery temperature or more using a trim heater even when heat capacity of the first heating medium is insufficient in the vaporizer.

[0040] Further, with a trim heater, the regasification system and method can prevent insufficient gasification of the 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 upon initial operation of the regasification system, thereby enabling stable operation of the regasification system.

[Description of Drawings]

[0041]

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

FIG. 2 is a diagram illustrating a configuration for controlling a pressure downstream of a vaporizer according to a first embodiment of the present invention.

FIG. 3 is a diagram illustrating a configuration for controlling a pressure downstream of a vaporizer according to a second embodiment of the present invention.

FIG. 4 is a diagram illustrating a configuration for controlling a pressure at an inlet of an expander-generator according to a third embodiment of the present invention.

FIG. 5 is a diagram illustrating a configuration for controlling a pressure at an inlet of an expander-generator according to a fourth embodiment of the present invention.

[Best Mode]

[0042] 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.

[0043] 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.

[0044] 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.

[0045] 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.

[0046] In addition, in one embodiment of the present 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.

[0047] Further, the LNG regasification vessel according to the embodiments of the present invention may regasify LNG at sea to supply the regasified LNG to onshore gas consumers via a pipe network (regas network).

[0048] A liquefied gas regasification system and method for vessels according to one embodiment of the present invention will be described with reference to FIG. 1 to FIG. 5.

[0049] An LNG regasification system for vessels according to one embodiment of the present invention may include a high-pressure pump (not shown) that compresses LNG discharged from an LNG storage tank (not shown) to a pressure or more required for gas consumers (not shown), a vaporizer 120 that gasifies the high pressure LNG compressed by the high pressure pump, 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 a gas consumer or completely gasifies LNG not gasified by the vaporizer 120 and heats the LNG to the temperature required for the gas consumer.

[0050] 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. The power pump may be a semi-submersible pump that is disposed in the LNG storage tank and can be operated in a state of being submerged in LNG stored in the LNG storage tank.

[0051] According to this embodiment, the high-pressure pump 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 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.

[0052] 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 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 a 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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.

[0057] According to this embodiment, LNG stored in the LNG storage tank is compressed by the high-pressure pump, 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.

[0058] The liquefied gas line LL may be provided with a first valve LV disposed upstream of the vaporizer 120 to regulate a flow rate of LNG supplied to the vaporizer 120.

[0059] The first valve LV is controlled based on an output signal corresponding to a temperature measured by a second temperature controller TIC02, which measures the temperature of the first heating medium discharged from the vaporizer 120 after heat exchange with LNG, and an output signal corresponding to a temperature measured by a first temperature controller TIC01, which measures the temperature of natural gas gasified by and discharged from the vaporizer 120.

[0060] In this embodiment, the first temperature controller TIC01 may refer to a device that includes both a temperature measurement unit TT01 adapted to measure temperature and a temperature controller adapted to calculate output values for controlling various devices for temperature regulation in response to the measured temperature value output from the temperature measurement unit TT01 and to send control signals to the various devices.

[0061] Further, the second temperature controller TIC02 may refer to a device that includes both a temperature measurement unit TT02 adapted to measure a temperature and a temperature controller adapted to calculate output values for controlling various devices for temperature regulation in response to the measured temperature value output from the temperature measurement unit TT02 and to send control signals to the various devices.

[0062] A first controller LS 1 controlling the first valve LV may be a low selector. That is, the first controller LS 1 may control the first valve LV based on a smaller value among an output signal corresponding to the temperature measured by the second temperature controller TIC02 and an output signal corresponding to the temperature measured by the first temperature controller TIC01.

[0063] In addition, the liquefied-gas regasification system according to this embodiment may include a first cycle that circulates a first heating medium as a heat source for gasifying LNG through heat exchange with LNG in the vaporizer 120.

[0064] According to this embodiment, the first heating medium may be a refrigerant undergoing phase change while circulating in the first cycle.

[0065] Conventionally, the vaporizer 120 mainly uses glycol water as a heating medium to vaporize LNG. When glycol water is adopted as the heating medium, phase change does not occur in the course of heat exchange with LNG in the vaporizer 120 and heat exchange with seawater in the heat exchanger. That is, heat transfer is achieved only using sensible heat.

[0066] On the contrary, when a refrigerant undergoing phase change in the course of heat exchange with LNG in the vaporizer 120 and heat exchange with seawater in the heat exchanger is adopted as the heating medium, heat transfer is achieved using sensible heat. Under the same condition of a duty ratio for gasification of LNG, since the flow rate of the heating medium to be cycled is significantly reduced, compared with the case of using glycol water, power of a pump for circulating the heating medium can be reduced, thereby enabling improvement in efficiency of the overall system.

[0067] 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.

[0068] 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.

[0069] 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.

[0070] 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.

[0071] 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.

[0072] 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 stepwise heated, 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.

[0073] Further, the first heat exchanger 220 according to this embodiment may be a shell & tube heat exchanger or a plate-type heat exchanger.

[0074] 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 work of first heating medium is converted into power. Power generated by the expander-generator 230 may be used by an on-board power consumer.

[0075] A first flow rate valve FV1 may be disposed downstream of the first pump 210 of the first heating medium line RL to regulate the flow rate of the first heating medium supplied from the first pump 210 to the first heat exchanger 220.

[0076] The first flow rate valve FV1 may be controlled by a fourth controller LS2 based on output signals corresponding to the rotational speed or load of the first pump 210, the temperature of the first heating medium discharged from the first heat exchanger 210 after heat exchange, and the flow rate of natural gas discharged from the vaporizer 120 after heat exchange.

[0077] The fourth controller LS2 may be a low selector. That is, the fourth controller LS2 may control the first flow rate valve FV1 based on the smallest value among an output value corresponding to the rotational speed or load of the first pump 210, an output value corresponding to the temperature of the first heating medium discharged from the first heat exchanger 210 after heat exchange, and an output value corresponding to the flow rate of natural gas discharged from the vaporizer 120 after heat exchange.

[0078] 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.

[0079] 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 onshore gas consumers.

[0080] According to this embodiment, 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 upward pressure corresponding to retardation of response rate of 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.

[0081] In addition, according to this embodiment, the first cycle may further include a knock-out drum 250 disposed between the first heat exchanger 220 and the expander-generator 230. The knock-out drum 250 temporarily stores the first heating medium gasified in the first heat exchanger 220 before the first heating medium is supplied to the expander-generator 230 and separates a liquid phase from the first heating medium to be supplied to the expander-generator 230.

[0082] A first heating medium line RL disposed between the knock-out drum 250 and the expander-generator 230 is provided with a second flow rate valve FV2 adapted to regulate the flow rate of the first heating medium having a gas phase and supplied from the knock-out drum 250 to the expander-generator 230.

[0083] The second flow rate valve FV2 may be controlled based on load for power generation or the rotational speed of the expander-generator 230, the pressure of the first heating medium expanded by the expander-generator 230 and discharged therefrom, and the pressure of the knock-out drum 250.

[0084] Further, the first heating medium having a gas phase may be controlled to flow from the knock-out drum 250 along the first heating medium line RL or the first branch-off line RL1 by controlling the second flow rate valve FV2 and a third flow rate valve FV3 provided to the first branch-off line RL1 based on the load for power generation or the rotational speed of the expander-generator 230, the pressure of the first heating medium expanded by the expander-generator 230 and discharged therefrom, and the pressure of the knock-out drum 250.

[0085] The second flow rate valve FV2 and the third flow rate valve FV3 may be controlled by a governor based on an output signal corresponding to at least one selected from among a pressure downstream of the expander-generator 230, a power generation load of the expander-generator 230, a rotational speed of the expander-generator 230, and the pressure of the knock-out drum 250.

[0086] 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.

[0087] 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.

[0088] 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.

[0089] According to this embodiment, the regasification system may further include a pressure regulation unit that regulates the pressure of the receiver 240. The pressure regulation unit of the receiver 240 includes a second valve RV and a third valve QV.

[0090] According to this embodiment, the regasification system may further include a fourth branch-off line RL4 branched off downstream of the first pump 210 from the first heating medium line RL and connected to the receiver 240 and a fifth branch-off line RL5 branched off from the knock-out drum 250 and connected to the fourth branch-off line RL4.

[0091] In order to maintain the minimum flow rate of the first pump 210, the fourth branch-off line RL4 is provided with a first level valve LV1 to return a certain amount of the first heating medium to the receiver when the amount of the first heating medium discharged from the first pump 210 exceeds the amount of the first heating medium required for the first heat exchanger 220, as in the case where the flow rate of the first heating medium required for the first heat exchanger 220 is less than the minimum flow rate. The first level valve LV1 may be controlled based on an output signal corresponding to a rotational number of the first pump 210.

[0092] Further, the fifth branch-off line RL5 is provided with a second level valve LV2 controlled to allow the first heating medium having a liquid phase and separated by the knock-out drum 250 to return to the receiver 240. The second level valve LV2 may be controlled based on an output signal corresponding to a water level of the knock-out drum 250.

[0093] In this embodiment, the first heating medium may be selected from materials or mixtures thereof undergoing phase change while circulating in the first cycle. 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.

[0094] 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.

[0095] In the expander-generator 230, the first heating medium isentropically expands and undergoes decrease in temperature in this process.

[0096] 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.

[0097] Thus, according to the embodiment, the regasification system further includes the trim heater 130 that heats the temperature of 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.

[0098] 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.

[0099] 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.

[0100] 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.

[0101] The second cycle according to this embodiment includes a second pump adapted to circulate a second heating medium, a second heat exchanger (not shown) adapted to heat or gasify the second heating medium, and an expansion tank (not shown) adapted to stabilize the second heating medium discharged from the trim heater 130 after heat exchange.

[0102] 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, gasified or heated by the second heat exchanger, cooled or condensed in the trim heater 130, and supplied to the second pump through the expansion tank while flowing along a second heating medium line (not shown).

[0103] In the second heat exchanger according to this embodiment, a heat source for heating the second heating medium may be seawater suctioned by the seawater pump and supplied to the second heat exchanger along a second seawater line.

[0104] In the second heat exchanger, seawater is cooled while gasifying or heating the second heating medium and the cooled seawater may be discharged from the second heat exchanger along the second seawater line.

[0105] In this embodiment, seawater is used as a heat source for gasifying or heating the second heating medium in the second heat exchanger 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.

[0106] Further, the second heat exchanger according to this embodiment may be a plate-type heat exchanger.

[0107] The expansion tank 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.

[0108] Further, in the expansion tank, 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.

[0109] In this embodiment, the second heating medium may be glycol water.

[0110] 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. 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.

[0111] 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.

[0112] In general, LNG is compressed above the lowest pressure condition in the high-pressure pump 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.

[0113] 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.

[0114] 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.

[0115] 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.

[0116] 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.

[0117] 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.

[0118] 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 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.

[0119] Further, upon initial operation 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.

[0120] 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 upon initial operation of the regasification system, thereby enabling stably operation of the regasification system.

[0121] In this embodiment, since power is generated by the first heating medium in the expander-generator 230, it is possible to reduce load and fuel consumption of an engine provided to the regasification vessel.

[0122] As such, according to this embodiment, power is generated by operating the expander-generator 230 using cold heat of the first heating medium having a high pressure and a gas phase, and LNG is gasified using the first heating medium having a low pressure and a gas phase after operation of the expander-generator 230. Here, it is important to control a pressure at an inlet side of the expander-generator 230, which is a high pressure side, and a pressure at an outlet side of the expander-generator 230, which is a low pressure side.

[0123] To this end, the receiver 240 serves to regulate the outlet pressure of the expander-generator 230 and acts as a buffering tank to allow the first heating medium having a liquid phase to be stably supplied to the first pump 210.

[0124] When the regasification system is normally operated, the temperature of the first heating medium discharged from the vaporizer 120 after heat exchange with LNG in the vaporizer 120 is reduced. Here, the temperature of the first heating medium discharged from the vaporizer 120 may be regulated by regulating the flow rate of LNG subjected to heat exchange with the first heating medium, that is, the flow rate of LNG supplied to the vaporizer 120.

[0125] Since the saturation pressure of the first heating medium is determined depending upon the temperature of the first heating medium condensed and discharged from the vaporizer 120 after heat exchange, it is desirable that the temperature of the first heating medium discharged from the vaporizer 120 be normally regulated in order to maintain a normal pressure of the first heating medium discharged from the expander-generator 230.

[0126] That is, it is desirable that the pressure of the receiver 240 be maintained at a saturation pressure depending upon the temperature of the first heating medium discharged from the vaporizer 120.

[0127] In normal circumstances, the pressure of the receiver 240 is stably controlled and maintained depending upon the temperature of the first heating medium. However, when transient increase in the flow rate of the first heating medium having a gas phase and entering the receiver 240 occurs, the pressure of the receiver 240 may not follow the temperature of the first heating medium due to a low response speed, even if the temperature of the first heating medium discharged from the vaporizer 120 is normally controlled.

[0128] Thus, in the regasification system and method according to the embodiment of the present invention, the pressure downstream of the expander-generator 230, that is, the low pressure-side pressure, is controlled to improve control responsiveness of the regasification system even in a situation where the response speed is delayed, as described above.

[0129] More specifically, the pressure downstream of the vaporizer 120, that is the pressure of the receiver 240, is controlled to achieve rapid control of the pressure downstream of the expander-generator 230.

[0130] Referring to FIG. 2, a regasification system according to a second embodiment of the present invention includes: a second branch-off line RL2 branched off downstream of the expander-generator 230 from the first heating medium line RL and connected to the receiver 240; a second valve RV provided to the second branch-off line RL2; a third branch-off line RL3 branched off upstream of the receiver 240 from the first heating medium line RL and connected upstream of the receiver 240; and a third valve QV provided to the third branch-off line RL3.

[0131] The regasification system further includes a first pressure controller PIC01 measuring the pressure of the receiver 240 and a second controller BQ controlling the second valve RV and the third valve QV depending upon an output signal corresponding to the pressure measured by the first pressure controller PIC01.

[0132] In this embodiment, the first pressure controller PIC01 may refer to a device that includes both a pressure measurement unit PT01 adapted to measure a pressure and a pressure controller adapted to calculate output values for controlling various devices for pressure regulation in response to the measured pressure value output from the pressure measurement unit PT01 and to send control signals to the various devices.

[0133] A control logic of the second controller BQ employs split range control and includes a bypass mode in which the second valve RV is opened to allow the first heating medium having a high temperature to be supplied from the expander-generator 230 to the receiver 240 after bypassing the vaporizer 120 along the second branch-off line RL2, when the pressure of the receiver 240 measured by the first pressure controller PIC01 is less than a preset value

[0134] In addition, the control logic of the second controller BQ includes a quenching mode in which the third valve QV is opened to allow the first heating medium discharged from the vaporizer 120 and having a low temperature to be supplied to the receiver 240 along the third branch-off line RL3 through a spray nozzle at an upper end of the receiver 240, when the pressure of the receiver 240 measured by the first pressure controller PIC01 is greater than a preset value.

[0135] In the bypass mode, when the pressure of the receiver 240 measured by the first pressure controller decreases below a preset value, the second valve RV may be rapidly opened to allow the first heating medium having a high temperature to flow into the receiver 240 such that the pressure of the receiver 240 can be increased while preventing decrease in pressure at the outlet of the expander-generator 230.

[0136] The bypass mode may be continued until the pressure of the receiver 240 measured by the first pressure controller reaches a preset value.

[0137] Normally, the first heating medium is supplied to the receiver 240 through a fluid inlet disposed at an intermediate height of the receiver 240 along the first heating medium line RL, and in the quenching mode, the third valve QV is opened to allow the first heating medium having a low temperature to be supplied to the receiver 240 through the spray nozzle disposed at the upper end of the receiver 240 so as to reduce the pressure inside the receiver 240 by reducing the temperature of the first heating medium present at an upper portion of the receiver 240 and having a high temperature and a gas phase. It is possible to achieve rapid control to prevent the pressure at the outlet of the expander-generator 230 from increasing by reducing the pressure inside the receiver 240.

[0138] The quenching mode may be continued until the pressure of the receiver 240 measured by the first pressure controller reaches a preset value.

[0139] On the other hand, a relationship between saturation and temperature may be changed from an initial value due to various factors including an actual composition of the first heating medium and the like. For example, when the first heating medium is a complex refrigerant mixed with several components, the composition of the first heating medium may be changed due to loss of some components having low boiling points during operation, thereby causing change in the relationship between saturation and temperature.

[0140] As such, if the regasification system is operated while maintaining initial preset values for various temperature and pressure measurement values of the second controller BQ despite change in composition of the first heating medium after an initial operation stage, excessive valve manipulation can occur corresponding to the bypass mode and the quenching mode due to the difference therebetween.

[0141] In order to solve this problem, the regasification system according to the second embodiment of the present invention includes a set point adjustment unit adapted to adjust a saturation curve relationship between pressure and temperature.

[0142] Referring to FIG. 3, the regasification system according to the second embodiment includes a third controller PID, which changes a preset value of the second temperature controller TIC02 using the pressure measurement value of the first pressure controller PIC01, as the set point adjustment unit.

[0143] That is, even if the composition of the first heating medium is changed, the regasification system can be normally controlled through adjustment of the preset pressure of the receiver 240 and opening timing of the second valve BV and the third valve QV corresponding to change in the composition of the first heating medium by adjusting the preset value of the temperature of the first heating medium discharged from the vaporizer 120, that is, a saturation temperature of the first heating medium, according to the saturation pressure of the receiver 240.

[0144] In normal operation of the LNG regasification system according to this embodiment, the first heating medium is condensed through heat exchange with LNG in the vaporizer 120 and circulates in the first cycle while maintaining a relatively low pressure.

[0145] Further, in order to control the pressure upstream of the expander-generator 230, that is, a high pressure-side pressure of the first cycle, the opening degrees of the second flow rate valve FV2 and the third flow rate valve FV3 disposed upstream of the expander-generator 230 are adjusted corresponding to the flow rate of the first heating medium circulating in the first cycle.

[0146] In order to maximize power generation by the expander-generator 230, it is desirable that the first heating medium be guided to flow into the expander-generator 230 along the first branch line RL1 rather than bypassing the expander-generator 230.

[0147] That is, when a restricted amount of the first heating medium is guided to flow towards the vaporizer 120, power generation by the expander-generator 230 can be increased as the opening degree of the third flow rate valve FV3 is decreased and the opening degree of the second flow rate valve FV2 is increased, thereby enabling advantageous operation of the entire system in terms of energy efficiency.

[0148] Thus, regasification systems and methods according to third and fourth embodiments of the present invention described below are characterized by controlling the pressure upstream of the expander-generator 230, that is, the high pressure-side pressure, in order to improve system efficiency.

[0149] Referring to FIG. 4, the regasification system according to the third embodiment controls the pressure upstream of the expander-generator 230 according to an output signal corresponding to the pressure of the knock-out drum 250.

[0150] According to this embodiment, the regasification system further includes: a second pressure controller PIC02 controlling the pressure of the knock-out drum 250, a fifth controller FB sending a signal corresponding to the pressure measurement value of the second pressure controller PIC02 to the sixth controller SIC and regulating an opening degree of the third flow rate valve FV3 based on an output value corresponding to the pressure measurement value of the second pressure controller PIC02, and a sixth controller SIC controlling the output and the rotational speed of the expander-generator 230 based on the output value corresponding to the pressure measurement value of the second pressure controller PIC02 and regulating an opening degree of the second flow rate valve FV2.

[0151] In this embodiment, the second pressure controller PIC02 may refer to a device that include both a pressure measurement unit PT02 adapted to measure the pressure of the knock-out drum 250 and a pressure controller adapted to calculate output values for controlling various devices for pressure regulation in response to the measured pressure value output from the pressure measurement unit PT02 and to send control signals to the various devices.

[0152] When the measured pressure value of the second pressure controller PIC02 is greater than a preset value, the fifth controller FB performs split range control and sends a signal to the sixth controller SIC to first open the second flow rate valve FV2 and the sixth controller SIC increases the output of the expander-generator 230 and opens or increases the opening degree of the second flow rate valve FV2 in response to the signal from the fifth controller FB so as to maintain the rotational speed of the expander-generator 230.

[0153] Despite the opening degree of the second flow rate valve FV2 reaching 100%, that is, the maximum opening degree, when the pressure of the knock-out drum 250 is greater than a preset value or the output of the expander-generator 230 reaches the maximum value, the fifth controller FB opens the third flow rate valve FV3 to allow the first heating medium to flow into the first branch-off line RL1 through split range control, thereby controlling the pressure of the knock-out drum 250, that is, the pressure upstream of the expander-generator 230.

[0154] According to this embodiment, the sixth controller SIC may be a governor (see FIG. 1). That is, according to this embodiment, for stable power supply, the opening degree of the second flow rate valve FV2 may be controlled by the governor, which controls the output of the expander-generator 230 by monitoring whether the turbine rotation speed of the expander-generator 230 is suitably maintained within a preset range and controlling the rotational speed of the expander-generator 230.

[0155] On the other hand, an output conversion speed of the expander-generator 230 may vary depending upon a manufacturer of the expander-generator 230, in which an allowable variation of the output conversion speed is 10% per minute on average. That is, for increasing the output of the expander-generator 230, it is desirable that the output of the expander-generator 230 be increased by 10% per minute or less.

[0156] As described above, upon variation of the output (turbine rotation speed) of the expander-generator 230 according to the pressure of the knock-out drum 250, in a transient condition in which variation in circulation amount of the first heating medium is faster than the rate of adjusting the output of the expander-generator 230 or in which the flow rate of the first heating medium having a gas phase and flowing into the knock-out drum 250 suddenly increases, the inlet pressure of the expander-generator 230 significantly increases above an allowable pressure range, causing overload of the regasification system. As a result, the expander-generator 230 cannot be stably operated.

[0157] In order to solve this problem, the regasification method according to the fourth embodiment allows rapid control of the pressure upstream of the expander-generator 230 by first opening the third flow rate valve FV3 depending upon the output value corresponding to the pressure measurement value of the second pressure controller PIC02.

[0158] According to this embodiment, when the pressure measurement value of the second pressure controller PIC02 is greater than a preset value, the third flow rate valve FV3 is first opened to allow the first heating medium to be discharged from the knock-out drum 250 to the first branch line RL1 by an excess pressure such that the inlet pressure of the expander-generator 230 can be rapidly reduced to an allowable pressure range (preset value).

[0159] Further, unlike the third embodiment wherein the fifth controller FB controls the third flow rate valve FV3 in response to the signal corresponding to the pressure measurement value output from the pressure controller of the second pressure controller PIC02, the pressure controller of the second pressure controller PIC02 according to this embodiment directly sends a signal for controlling the opening degree to the third flow rate valve FV3 depending upon the output value corresponding to the pressure measurement value thereof.

[0160] Further, according to this embodiment, the regasification system further includes a seventh controller ZIC that controls the third flow rate valve FV3, as shown in FIG. 5.

[0161] According to this embodiment, the seventh controller ZIC regulates the opening degree of the second flow rate valve FV2 such that load is allocated to the expander-generator 230 so as to set the opening degree of the third flow rate valve (FV3) to a closed state (SP: 0%).

[0162] As such, according to this embodiment, when the pressure of the knock-out drum 250 is greater than a preset value, the third flow rate valve FV3 is first open to set the inlet pressure of the expander-generator 230 to a preset value.

[0163] Next, the seventh controller ZIC sends a signal to the sixth controller SIC to reduce the opening degree of the third flow rate valve (FV3) as much as possible while maximizing the output of the expander-generator 230.

[0164] As a result, the sixth controller SIC increases the opening degree of the second flow rate valve FV2 as much as possible, thereby changing the output of the expander-generator 230 within an allowable range and maximizing power generation while maintaining the pressure upstream of the expander-generator 230.

[0165] Although some embodiments have been described herein, it should be understood 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.

<List of Reference Numerals>

120:	Vaporizer	130:	Trim heater
210:	First pump	220:	First heat exchanger
230:	Expander-generator	240:	Receiver
250:	Knock-out drum		
LL:	Liquefied gas line	RL:	First heating medium line
RL1:	First branch-off line	RL2:	Second branch-off line
RL3:	Third branch-off line	RL4:	Fourth branch-off line
RL5:	Fifth branch-off line	SL1:	First seawater line
LV:	First valve	FV1:	First flow rate valve
FV2:	Second flow rate valve	FV3:	Third flow rate valve
LV1:	First water level valve	LV2:	Second water level valve
RV:	Second valve	QV:	Third valve
TIC01:	First temperature controller	TIC02:	Second temperature controller
PIC01:	First pressure controller	PIC02:	Second pressure controller
LS1:	First controller	BQ:	Second controller
PID:	Third controller	LS2:	Fourth controller
FB:	Fifth controller	SIC:	Sixth controller
ZIC:	Seventh controller		

Claims

1. A liquefied-gas regasification method of a vessel, comprising:

gasifying liquefied gas through heat exchange with a first heating medium in a vaporizer; and
recovering cold heat from the first heating medium discharged from the vaporizer to recirculate the cold heat to the vaporizer,
wherein recovering the cold heat from the first heating medium comprises: gasifying the first heating medium in a first heat exchanger, the first heating medium being condensed into a liquid phase through heat exchange in the vaporizer; supplying the gasified first heating medium to an expander-generator to generate power through expansion of the gasified first heating medium; and supplying the expanded first heating medium to the vaporizer

while controlling a pressure upstream or downstream of the expander-generator to control a pressure downstream of the vaporizer.

2. The liquefied-gas regasification method according to claim 1:

wherein a receiver receives the first heating medium discharged from the vaporizer and the first heating medium discharged from the receiver is gasified in order to control a pressure downstream of the expander-generator, and wherein, when a pressure measurement value of the receiver is less than a preset value, a liquefied-gas regasification system is operated in a bypass mode in which the first heating medium expanded in the expander-generator and having a high temperature is supplied to the receiver after bypassing the vaporizer, and, when the pressure measurement value of the receiver is greater than a preset value, the liquefied-gas regasification system is operated in a quenching mode in which the first heating medium discharged from the vaporizer and having a low temperature is supplied into the receiver through a spray nozzle disposed at an upper end of the receiver.

3. The liquefied-gas regasification method according to claim 1, wherein the first heating medium undergoes phase change through heat exchange in the vaporizer and the first heat exchanger.

4. The liquefied-gas regasification method according to claim 1, wherein a flow rate of the liquefied gas supplied to the vaporizer is regulated to maintain a preset temperature of the first heating medium having a low temperature and discharged from the vaporizer after heat exchange and a preset temperature of the regasified gas discharged from the vaporizer after heat exchange.

5. The liquefied-gas regasification method according to claim 1, wherein a flow rate of the liquefied gas supplied to the vaporizer is regulated based on a smaller value among an output value for maintaining a preset temperature of the first heating medium having a low temperature and discharged from the vaporizer after heat exchange and an output value for maintaining a preset temperature of the regasified gas discharged from the vaporizer after heat exchange.

6. The liquefied-gas regasification method according to claim 1, wherein the regasified gas gasified in the vaporizer is heated to a temperature required for a gas consumer through heat exchange with a second heating medium.

7. The liquefied-gas regasification method according to claim 1, wherein, when a pressure downstream of the expander-generator is less than a preset value or a power generation load is low, the first heating medium having a gas phase is regulated to flow downstream of the expander-generator after bypassing the expander-generator.

8. The liquefied-gas regasification method according to claim 1, wherein a knock-out drum receives the first heating medium gasified in the first heat exchanger before the gasified first heating medium is supplied to the expander-generator, and, when a pressure measurement value of the knock-out drum is greater than a preset value, a pressure upstream of the expander-generator is controlled by increasing an output of the expander-generator.

9. The liquefied-gas regasification system according to claim 8, wherein increasing the output of the expander-generator increases an opening degree of a second flow rate valve allowing the first heating medium to flow from the knock-out drum to the expander-generator and is performed corresponding to the opening degree of the second flow rate valve.

10. The liquefied-gas regasification system according to claim 9, wherein a rotational speed of the expander-generator is controlled by a sixth controller and the opening degree of the second flow rate valve is regulated by the sixth controller in response to a control signal sent from a fifth controller depending upon the pressure measurement value.

11. The liquefied-gas regasification system according to claim 9, wherein, when the opening degree of the second flow rate valve reaches a maximum degree or the output of the expander-generator reaches a maximum output, the fifth controller opens a third flow rate valve to allow the first heating medium to flow downstream of the expander-generator from the knock-out drum after bypassing the expander-generator.

12. The liquefied-gas regasification system according to claim 8, wherein increasing the output of the expander-generator comprises opening the third flow rate valve to allow the first heating medium to flow downstream of the expander-generator from the knock-out drum after bypassing the expander-generator, increasing the output of the expander-

generator within an allowable output range of the expander-generator while decreasing the opening degree of the third flow rate valve, and increasing the opening degree of the second flow rate valve to allow the first heating medium to flow from the knock-out drum to the expander-generator.

13. The liquefied-gas regasification system according to claim 12, wherein a rotational speed of the expander-generator is controlled by a sixth controller and a seventh controller managing a variation of the third flow rate valve sends a signal to the sixth controller to increase the rotational speed of the expander-generator until the opening degree of the third flow rate valve reaches 0%.

14. The liquefied-gas regasification method according to claim 1, wherein a circulation flow rate of the first heating medium is determined based on a heating duty of the vaporizer.

15. A liquefied-gas regasification system of a vessel, comprising:

a vaporizer gasifying liquefied gas through heat exchange with a first heating medium;
a first heat exchanger gasifying the first heating medium condensed into a liquid phase by heat exchange in the vaporizer;
an expander-generator expanding the first heating medium gasified in the first heat exchanger to generate power; and
a pressure controller controlling a pressure upstream or downstream of the expander-generator,
wherein a pressure downstream of the vaporizer is controlled by controlling the pressure upstream or downstream of the expander-generator.

16. The liquefied-gas regasification method according to claim 15, further comprising:

a receiver receiving the first heating medium having a low temperature and discharged from the vaporizer after heat exchange;
a first heating medium line along which the first heating medium expanded by the expander-generator is delivered from the expander-generator to the vaporizer and the first heating medium recovering cold heat of the liquefied gas is delivered from the vaporizer to the receiver;
a second valve disposed downstream of the expander-generator to allow the first heating medium to flow to the receiver after bypassing the vaporizer;
a third valve allowing the first heating medium discharged from the vaporizer to be supplied into the receiver through a spray nozzle disposed at an upper end of the receiver; and
a second controller opening the second valve when a pressure measurement value of the receiver is less than a preset value and opening the third valve when the pressure measurement value of the receiver is greater than a preset value.

17. The liquefied-gas regasification method according to claim 16, further comprising:

a first valve regulating a flow rate of the liquefied gas supplied to the vaporizer; and
a first controller controlling the first valve to maintain a preset temperature of the first heating medium having a low temperature and discharged from the vaporizer after heat exchange and to maintain a preset temperature of the regasified gas discharged from the vaporizer after heat exchange.

18. The liquefied-gas regasification method according to claim 17, according to claim 9, further comprising:

a third controller adjusting the preset temperature of the first heating medium depending upon the pressure measurement value of the receiver
wherein the preset temperature of the first heating medium is a saturation temperature of the first heating medium.

19. The liquefied-gas regasification method according to claim 16, further comprising:

a third flow rate valve allowing the first heating medium gasified in the first heat exchanger to flow downstream of the expander-generator after bypassing the expander-generator; and
a governor controlling the third flow rate valve depending upon a pressure downstream of the expander-generator and a power generation load of the expander-generator.

20. The liquefied-gas regasification method according to claim 15, further comprising:

a knock-out drum receiving the first heating medium gasified in the vaporizer;
a second flow rate valve allowing the first heating medium discharged in a gas phase from the knock-out drum to be supplied to the expander-generator through regulation of an opening degree thereof;
a third flow rate valve allowing the first heating medium discharged in a gas phase from the knock-out drum to bypass the expander-generator through regulation of an opening degree thereof; and
a sixth controller controlling an output of the expander-generator depending upon a pressure measurement value of the knock-out drum and regulating the opening degree of the second flow rate valve depending upon the output of the expander-generator to control a pressure upstream of the expander-generator.

21. The liquefied-gas regasification system according to claim 20, further comprising:
a fifth controller sending a signal for increasing the output of the expander-generator to the sixth controller depending upon the pressure measurement value of the knock-out drum and opening the third flow rate valve when the output of the expander-generator reaches a maximum output.

22. The liquefied-gas regasification system according to claim 20, further comprising:

a pressure controller opening the third flow rate valve when the pressure measurement value of the knock-out drum is greater than a preset value; and
a seventh controller sending a signal for increasing a rotational speed of the expander-generator to the sixth controller until the opening degree of the third flow rate valve reaches a minimum value.

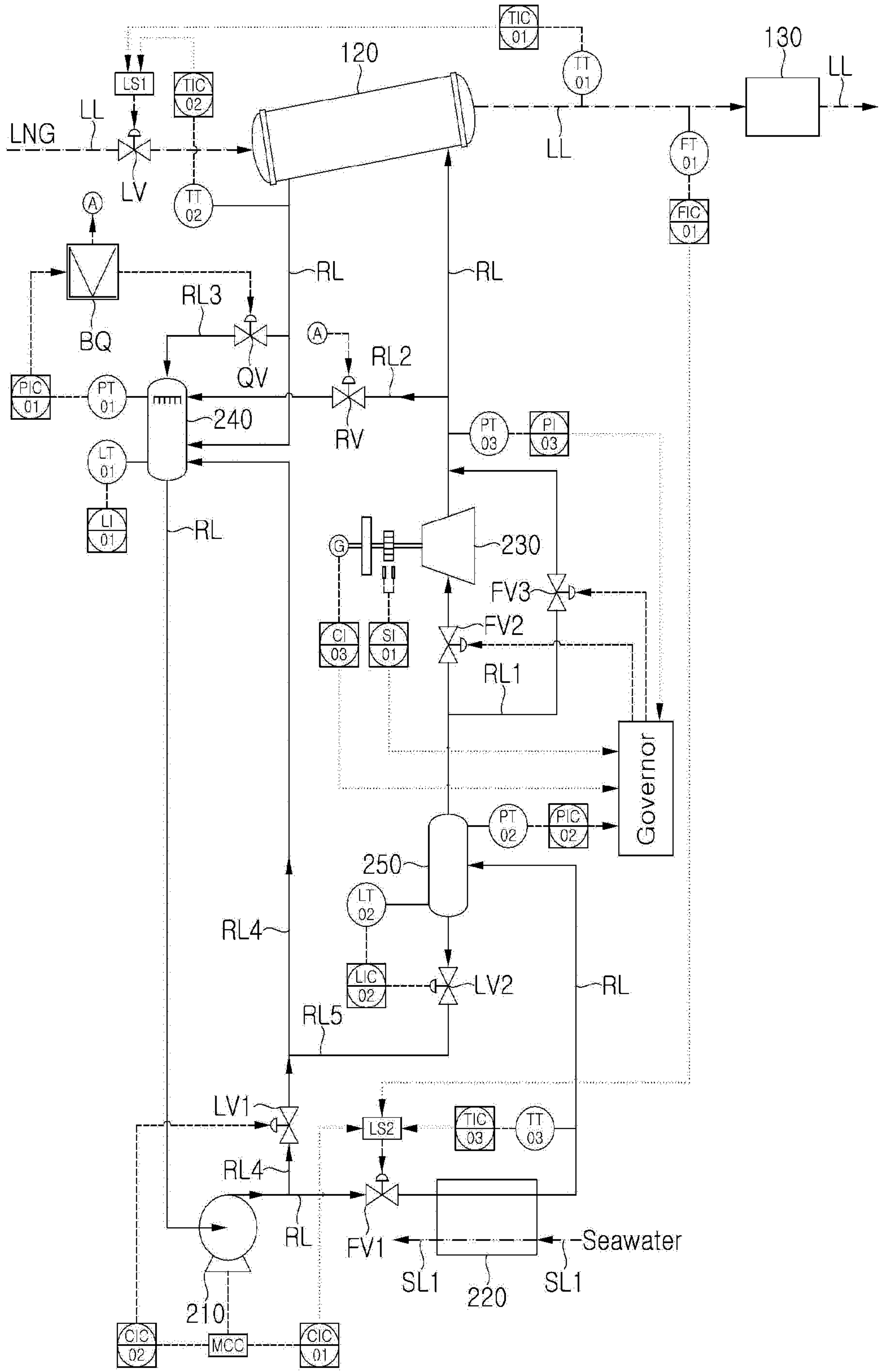
23. The liquefied-gas regasification method according to claim 15, wherein the vaporizer is a 1-pass type shell & tube heat exchanger.

24. The liquefied-gas regasification method according to claim 15, further comprising:
a trim heater additionally heating the regasified gas gasified in the vaporizer to a temperature required for a gas consumer.

25. The liquefied-gas regasification system according to claim 24, further comprising:
a second cycle in which a second heating media recovering cold heat of the regasified gas through heat exchange with the regasified gas in the trim heater is circulated.

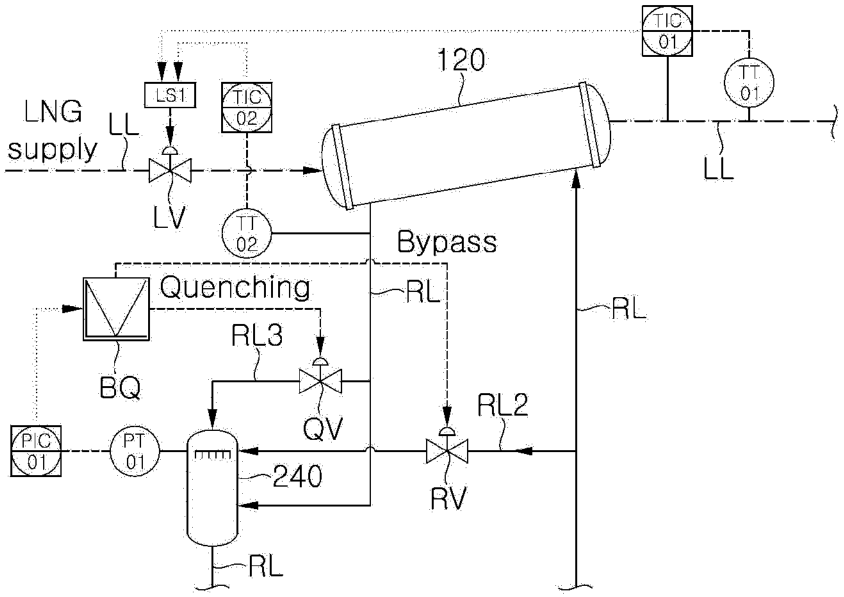
26. The liquefied-gas regasification system according to claim 24, wherein the trim heater is a 2-pass type shell & tube heat exchanger.

【FIG. 1】



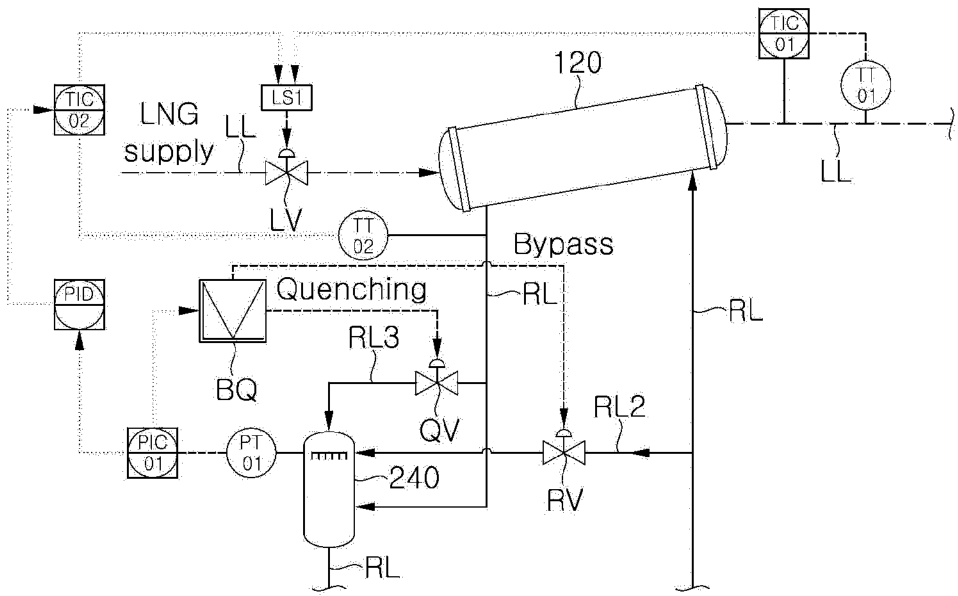
TIC 01
120
130
LL
LS1
TIC 02
TT 01
LNG
LL
LV
LL
TT 02
FT 01
FIC 01
A
BQ
RL3
RL
RL
QV
A
RL2
PIC 01
PT 01
240
RV
PT 03
PI 03
LT 01
LI 01
RL
G
230
FV3
FV2
CI 03
SI 01
RL1
Governor
250
PT 02
PIC 02
LT 02
RL4
LIC 02
LV2
RL
RL5
LV1
LS2
TIC 03
TT 03
RL4
RL
FV1
Seawater
SL1
220
SL1
210
CIC 02
MCC
CIC 01

【FIG. 2】



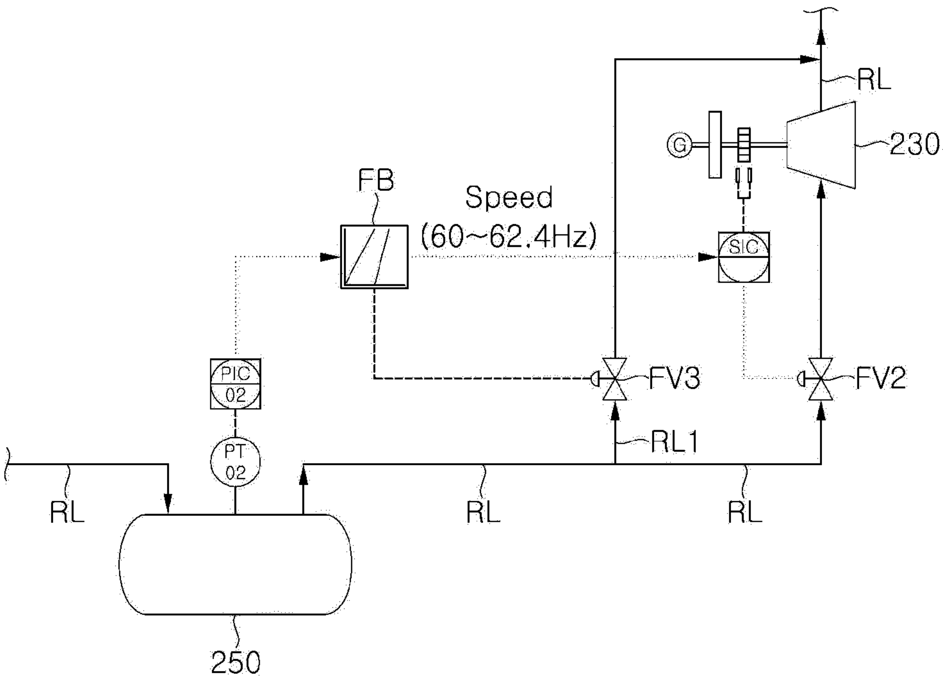
LS1
TIC 02
TIC 01
TT 01
120
LNG supply
LL
LV
TT 02
Bypass
Quenching
RL
BQ
RL3
QV
RL2
PIC 01
PT 01
240
RV

【FIG. 3】

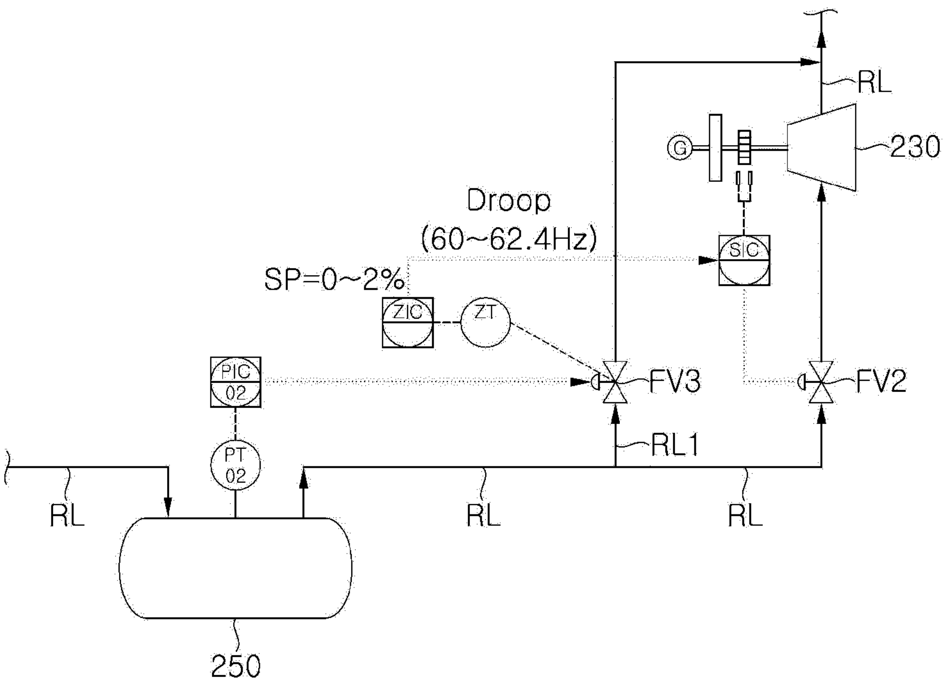


TIC 01
TT 01
120
LS1
TIC 02
LNG supply
LL
LV
TT 02
Bypass
PID
Quenching
RL
BQ
RL3
QV
RL2
PIC 01
PT 01
240
RV

【FIG. 4】


RL
230
FB
Speed
(60~62.4Hz)
SIC
PIC
02
FV3
FV2
PT
02
RL1
RL
RL
RL
250

【FIG. 5】


RL
230
Droop
(60~62.4Hz)
SIC
SP=0~2%
ZIC
ZT
PIC
02
FV3
FV2
PT
02
RL1
RL
RL
RL
250

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2020/018810

A. CLASSIFICATION OF SUBJECT MATTER

B63B 25/16(2006.01)i; **B63J 3/04**(2006.01)i; **F17C 9/00**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B63B 25/16(2006.01); B63H 21/38(2006.01); F01D 17/14(2006.01); F01K 25/10(2006.01); F17C 13/00(2006.01); F17C 9/02(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 기화기(vaporizer), 밸브(valve), 온도센서(temperature sensor), 제어(control), 발전기(generator)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	KR 10-2019-0110753 A (SAMSUNG HEAVY IND. CO., LTD.) 01 October 2019 (2019-10-01) See paragraphs [0019]-[0048] and [0055]-[0066] and figure 4.	1-3,6-7,14-16,19,23-26 4-5,8-13,17-18,20-22
Y	KR 10-2015-0127936 A (HYUNDAI HEAVY INDUSTRIES CO., LTD.) 18 November 2015 (2015-11-18) See paragraph [0075] and figure 1.	4-5,17-18
Y	KR 10-2012-0083906 A (CRYOSTAR SAS) 26 July 2012 (2012-07-26) See paragraphs [0025] and [0029] and figure 1.	8-13,20-22
A	JP 2016-114062 A (TADA, Masafumi) 23 June 2016 (2016-06-23) See claim 1 and figure 1.	1-26

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 June 2021	**30 June 2021**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208** Facsimile No. **+82-42-481-8578**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2019)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2020/018810

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007-0214807 A1 (FAKA, Solomon Aladja) 20 September 2007 (2007-09-20) See paragraphs [0043]-[0049] and figure 1.	1-26

Form PCT/ISA/210 (second sheet) (July 2019)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2020/018810

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2019-0110753 A	01 October 2019	KR 10-2095572 B1	31 March 2020
KR 10-2015-0127936 A	18 November 2015	KR 10-1899623 B1	05 October 2018
KR 10-2012-0083906 A	26 July 2012	BR 112012008281 A2	06 June 2017
		CN 102639923 A	15 August 2012
		CN 102639923 B	28 January 2015
		CY 1115878 T1	25 January 2017
		EP 2309165 A1	13 April 2011
		EP 2486321 A1	15 August 2012
		EP 2486321 B1	25 June 2014
		ES 2502365 T3	03 October 2014
		JP 2013-507585 A	04 March 2013
		JP 2016-048119 A	07 April 2016
		JP 6231064 B2	15 November 2017
		JP 6280304 B2	14 February 2018
		PT 2486321 E	22 September 2014
		US 2012-0317997 A1	20 December 2012
		WO 2011-042531 A1	14 April 2011
JP 2016-114062 A	23 June 2016	CN 106460571 A	22 February 2017
		GB 2540080 A	04 January 2017
		GB 2540080 B	06 September 2017
		JP 5885114 B1	15 March 2016
		JP 5958730 B2	02 August 2016
		KR 10-1716751 B1	15 March 2017
		KR 10-2016-0140958 A	07 December 2016
		US 2017-0038008 A1	09 February 2017
		WO 2015-159894 A1	22 October 2015
US 2007-0214807 A1	20 September 2007	AU 2007-224990 A1	20 September 2007
		AU 2007-224990 B2	19 January 2012
		AU 2007-224991 A1	20 September 2007
		AU 2007-224992 A1	20 September 2007
		AU 2007-224992 B2	01 September 2011
		AU 2007-226253 A1	20 September 2007
		AU 2007-226253 B2	25 August 2011
		AU 2007-295937 A1	20 March 2008
		AU 2007-295938 A1	20 March 2008
		EP 1994326 A1	26 November 2008
		EP 1994326 B1	31 October 2018
		EP 1994327 A1	26 November 2008
		EP 1994328 A1	26 November 2008
		EP 2005055 A1	24 December 2008
		JP 2009-529455 A	20 August 2009
		JP 2009-530549 A	27 August 2009
		JP 5043047 B2	10 October 2012
		JP 5260326 B2	14 August 2013
		JP 5283514 B2	04 September 2013
		KR 10-1296822 B1	14 August 2013
		KR 10-1363998 B1	26 February 2014
		KR 10-2008-0111456 A	23 December 2008
		KR 10-2008-0111463 A	23 December 2008
		KR 10-2008-0113030 A	26 December 2008

Form PCT/ISA/210 (patent family annex) (July 2019)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2020/018810

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
		KR 10-2008-0113039 A	26 December 2008
		KR 10-2009-0057298 A	04 June 2009
		KR 10-2009-0060332 A	11 June 2009
		US 2007-0214804 A1	20 September 2007
		US 2007-0214805 A1	20 September 2007
		US 2007-0214806 A1	20 September 2007
		US 2009-0193780 A1	06 August 2009
		US 2009-0199575 A1	13 August 2009
		US 8069677 B2	06 December 2011
		US 8607580 B2	17 December 2013
		WO 2007-104076 A1	20 September 2007
		WO 2007-104077 A1	20 September 2007
		WO 2007-104078 A1	20 September 2007
		WO 2007-105042 A1	20 September 2007
		WO 2008-031146 A1	20 March 2008
		WO 2008-031147 A1	20 March 2008

Form PCT/ISA/210 (patent family annex) (July 2019)