

Description

Technical Field

5 **[0001]** The present invention relates to a method of operating a liquefied natural gas receiving facility configured to receive a liquefied natural gas (LNG) to store the LNG in a storage tank, vaporize the LNG, and send a product gas.

Background Art

10 **[0002]** Along with the widespread use of renewable energy, a decrease in reliability of an electric power system has become a concern. As a countermeasure against the decrease in reliability, introduction of "demand response" (hereinafter also referred to as "DR") has been under examination. The demand response is a technique of adjusting demand for electric power, with which a consumer side changes a power consumption pattern through electricity pricing or payment of incentives.

15 **[0003]** For example, a consumer such as a factory or a large retailer increases or decreases the demand for electric power by switching between operation and stop of a power consuming apparatus or changing an output of its own private power generation facility.

[0004] In implementation of the DR for reducing the demand for electric power ("down DR"), a consumer which is not equipped with, for example, a private power generation facility or a battery or is equipped with a private power generation facility or a battery having insufficient capability is inevitably required to reduce the demand for electric power. As a result, for example, production adjustment is required to be implemented at a factory in some cases. Thus, it is difficult for a consumer to participate in a system of the DR unless advantages in the implementation of the DR reliably surpass disadvantages caused by the production adjustment.

20 **[0005]** In Patent Literature 1, there is described a demand-response system configured to implement the DR. With this demand-response system, an electric power company directly outputs an electric-power-demand adjustment command signal to an electric-apparatus controller configured to control an operation of an electric apparatus on a consumer side. However, for the consumer which requires work for, for example, securing safety before starting an operation of an electric apparatus, it is difficult to participate in the demand-response system in which an outside electric power company directly controls the operation of the electric apparatus.

30 **[0006]** Further, in Patent Literature 2, there is described a technology of adjusting the amount of boil off gas (BOG: LNG component vaporized in an LNG tank) to be mixed with a liquefied natural gas that has been vaporized in a vaporizer through load control of a BOG compressor in accordance with a calorific value required by a gas consumer. Meanwhile, a technology relating to the DR is not described in Patent Literature 2.

35 Citation List

Patent Literature

[0007]

40 [PTL 1] JP 6343372 B2
[PTL 2] JP 2018-112218 A

Summary of Invention

45 Technical Problem

[0008] The present invention has been made under the circumstances described above, and has an object to provide a technology of enabling demand response (DR) while maintaining a stable operation of a liquefied natural gas receiving facility.

Solution to Problem

55 **[0009]** According to the present invention, there is provided a method of operating a liquefied natural gas receiving facility, the liquefied natural gas receiving facility including: a storage tank configured to store a liquefied natural gas received from an outside; vaporizers configured to vaporize the liquefied natural gas delivered from the storage tank so as to send the liquefied natural gas in a gaseous state; and a gas compression unit to be driven by an electric motor, which is configured to boost pressure of a boil off gas generated in the storage tank so as to mix the boil off gas boosted

in pressure with the natural gas vaporized in the vaporizers, the method including: an examination start step of starting examination of reduction in power consumption upon receiving a request for the reduction in power consumption, which contains information about a reduction time period, or in anticipation of reception of the request; a stoppable time period calculation step of predicting a change in internal pressure of the storage tank, which is caused when the gas compression unit is stopped, and calculating a stoppable time period of the gas compression unit; and a stoppability determination step of determining whether the gas compression unit is stoppable based on a result of comparison between the reduction time period and the stoppable time period of the gas compression unit.

[0010] The method of operating a liquefied natural gas receiving facility may have the following features.

(a) The method includes a gas compression unit stopping step of, when determination is made in the stoppability determination step that the gas compression unit is stoppable in the reduction time period, stopping the gas compression unit.

(b) The vaporizers include: a vaporizer for normal operation, which is configured to vaporize the liquefied natural gas with use of seawater supplied as a heat source through a seawater pump to be driven by an electric motor; and a vaporizer for emergency operation, which is configured to vaporize the liquefied natural gas with use of heat of combustion of the natural gas as a heat source, and the method further includes a vaporizer switching step to be executed in addition to execution of the gas compression unit stopping step, the vaporizer switching step of switching the vaporizer for normal operation to the vaporizer for emergency operation and vaporizing the liquefied natural gas.

(c) In the stoppable time period calculation step, the change in internal pressure is predicted based on a change in gas-phase volume, which is caused along with the delivery of the liquefied natural gas from the storage tank, and a boil off gas amount generated in the storage tank. The boil off gas amount generated in the storage tank is calculated based on a quantity of heat input to the storage tank.

(d) In the stoppable time period calculation step, a time period in which a prediction value of the change in internal pressure of the storage tank is less than an upper limit value of an operating pressure, which is set for the storage tank, is set as the stoppable time period.

(e) The method includes a continuation determination step of, when the reduction time period overlaps a time period in which the liquefied natural gas is received by the storage tank from the outside, determining prioritization of continuation of the operation of the gas compression unit.

(f) The method includes: a target pressure setting step of, when a result of determination in the stoppability determination step is negative, setting a target pressure lower than a pressure in the storage tank at a time of execution of the stoppability determination step so as to reduce power consumption; and a pressure reduction step of reducing the internal pressure of the storage tank to the target pressure, and the stoppability determination step is executed again after the pressure reduction step.

Advantageous Effects of Invention

[0011] According to an embodiment of the present invention, the stoppable time period of the gas compression unit configured to extract the boil off gas from the storage tank for the liquefied natural gas is calculated. Whether or not the gas compression unit is stoppable is determined based on the result of calculation. Thus, the demand response can be implemented without hindering the stable operation of the liquefied natural gas receiving facility.

Brief Description of Drawings

[0012]

FIG. 1 is an explanatory view for illustrating a relationship among participants in DR trading.

FIG. 2 is a configuration diagram of an LNG receiving facility according to an embodiment.

FIG. 3 is a flowchart with items to be implemented in the LNG receiving facility in association with DR.

Description of Embodiment

[0013] FIG. 1 is an illustration of an example of a relationship among participants in DR trading. A power transmission and distribution business operator 11 includes, for example, a general power transmission and distribution business operator such as a regional electric power company. When a contract for DR is made with the power transmission and distribution business operator 11, a reward may be given. Meanwhile, when a demand for the DR from the power transmission and distribution business operator 11 is not complied with, payment of a penalty is required in some cases.

[0014] A resource aggregator 12 performs supply and demand adjustment for the DR collectively for a plurality of consumers 13 so as to achieve distribution of a reward and reduction of a risk of payment of a penalty. Selection of the

consumer 13 which can comply with a request for the DR from the power transmission and distribution business operator 11 and allocation of a corresponding time period may be exemplified as contents of the supply and demand adjustment.

[0015] The consumers 13 each implements the DR in view of the supply and demand adjustment performed by the resource aggregator 12. The DR includes "up DR" for increasing electric power demand and "down DR" for reducing electric power demand. When, for example, the amount of power generation in renewable energy is large and thus electric power demand is required to be increased, a request for the "up DR" is issued. Meanwhile, when, for example, electric power demand is tight in a service area of the power transmission and distribution business operator 11, a request for the "down DR" is issued.

[0016] A business operator of an LNG receiving facility 2 of this example corresponds to one of the consumers 13 among the above-mentioned participants in the DR trading.

[0017] In the example illustrated in FIG. 1, the power transmission and distribution business operator 11 makes a request for the "down DR" (reduction request), which contains information about a reduction amount and a reduction time period, to the resource aggregator 12. In order to reduce power consumption so as to meet the reduction request, the resource aggregator 12 performs supply and demand adjustment for the plurality of consumers 13 (consumers A and B, and LNG receiving facility 2) in accordance with respective reducible amounts. In the example illustrated in FIG. 1, as a result of the adjustment, it is determined that the consumer A and the LNG receiving facility 2 carry out the "down DR". Then, when the consumer A and the LNG receiving facility 2 reduce power consumption amounts, the power transmission and distribution business operator 11 can obtain an effect of reducing an electric power load in accordance with the reduction request.

[0018] In this case, the LNG receiving facility 2 illustrated in FIG. 1 has a function of receiving an LNG from an outside to store the LNG, vaporizing the stored LNG, and sending the vaporized LNG to a demander 3. In some cases, the LNG receiving facility 2 has a facility configuration applicable to the DR in comparison to the consumer 13 such as a factory, which needs production adjustment for implementing the "down DR" (hereinafter referred to as "DR").

[0019] Now, a configuration example of the LNG receiving facility 2 of this example is described with reference to FIG. 2.

[0020] The LNG receiving facility 2 includes an LNG tank 21, LNG pumps 211 and 22, vaporizers (ORV 231 and SMV 232 described later), and a calorific-value adjusting unit 26. The LNG tank 21 is configured to store the LNG. The LNG pumps 211 and 22 are configured to feed the LNG from the LNG tank 21 so as to deliver a gas to the demander 3. The vaporizers are configured to vaporize the LNG into a state of avaporizedgas. Thecalorific-valueadjustingunit 26 is configured to add a liquefied petroleum gas (LPG) for calorific-value adjustment to the vaporized gas to obtain a product gas.

[0021] The LNG tank 21 is a storage tank configured to store, for example, the LNG received from an LNG tanker 4 under a state of a liquid cooled to about -162 degrees Celsius. A type (such as an aboveground tank, an underground tank, or an in-ground tank) and a capacity thereof are not particularly limited. In FIG. 2, there is illustrated an example of an aboveground tank in which an upper surface of a side wall having a cylindrical shape is covered with a dome-shaped roof.

[0022] The LNG stored in the LNG tank 21 is fed to the vaporizers 231 and 232 via the LNG pump 211 disposed in the LNG tank 21 and the feed pump 22 for boosting pressure.

[0023] The LNG receiving facility 2 of this example can switch, for use, between the open rack vaporizer (ORV) 231 and the submerged-combustion vaporizer (SMV) 232. The ORV 231 is a vaporizer configured to vaporize the LNG with use of seawater (S.W.), which is supplied through a seawater pump (not shown) driven by an electric motor, as a heat source. The SMV 232 is a vaporizer configured to vaporize the LNG with use of heat of combustion of a natural gas as a heat source. In the LNG receiving facility 2, the LNG is vaporized with use of the ORV 231 during normal operation, and the SMV 232 is in a standby state so as to be used for emergency operation at a time of, for example, a power failure. In the LNG receiving facility 2, for example, a plurality of ORVs 231 and a plurality of SMVs 232 are provided.

[0024] In place of the ORV 231, an intermediate fluid vaporizer (IFV) may be used as the vaporizer to be used for normal operation. The IFV is configured to heat an intermediate medium such as propane with use of seawater to vaporize the LNG with the intermediate medium. Also in the IFV, the seawater is supplied through a seawater pump driven by an electric motor.

[0025] The calorific-value adjusting unit 26 is configured to mix the LPG for calorific-value adjustment with the vaporized gas so as to send a product gas having a calorific value required at the demander 3. The LPG (butane or propane) stored in an LPG tank 25 is fed under a liquid state to the calorific-value adjusting unit 26 via an LPG pump 251. The LPG is vaporized with use of a heat medium and is mixed with the vaporized gas fed from the ORV 231 to turn into a product gas in the calorific-value adjusting unit 26. The product gas, which has been subjected to calorific-value adjustment in the calorific-value adjusting unit 26, is delivered to the demander 3.

[0026] Further, in the LNG tank 21 that stores the LNG, a part of the LNG is vaporized due to, for example, heat input from the outside, to generate a BOG. In order to prevent an excessive increase in pressure in the LNG tank 21, a BOG compressor 24 corresponding to a gas compression unit configured to extract the BOG is connected to the LNG tank 21. The BOG compressor 24 of this example is driven by an electric motor (not shown).

[0027] The BOG compressor 24 is a multi-stage BOG compressor including, for example, three compression stages

as illustrated in FIG. 2. The BOG compressor 24 is configured to boost pressure of the BOG having a pressure falling within a range of from about 12 kPaG to about 22 kPaG (suction-side pressure in a first compression stage) to a pressure falling within a range of from about 2 MPaG to about 7.5 MPaG (discharge-side pressure in a last compression stage). The BOG boosted in pressure joins the vaporized LNG in the vaporizer (ORV 231 or SMV 232). After the calorific value is adjusted, the BOG is delivered as the product gas to the demander 3.

[0028] In the LNG receiving facility 2 having the configuration described above, when the BOG compressor 24 is stopped, power consumption can be reduced by about several megawatts. Stopping the BOG compressor 24 does not affect the LNG pumps 211 and 22, and the feeding of the LNG can be continued. Further, when the ORV 231 is stopped, power consumption can be reduced by about several hundreds of kilowatts. In a case in which the ORV 231 is stopped, the vaporization of the LNG can be continued by operating the SMV 232.

[0029] In view of the above-mentioned configuration and operation, it can be said that, in the participation in the DR trading, the LNG receiving facility 2 corresponds to the consumer 13 having a facility configuration applicable thereto.

[0030] Meanwhile, when the BOG compressor 24 is stopped over a long time period and the pressure in the LNG tank 21 exceeds an upper limit value of an operating pressure, the BOG may be released, for example, toward a flare (not shown) and a loss resulting from combustion of the gas in the flare may occur. When the pressure in the LNG tank 21 further increases, a safety valve (not shown) is activated to diffuse a surplus BOG into an atmosphere.

[0031] In particular, in the LNG receiving facility 2, the LNG is received from the LNG tanker 4 about once to about several times a month. After the reception, the amount of generation of BOG in the LNG tank 21 increases to several times, for example, about four times that during a normal operation. It is sometimes difficult to stop the BOG compressor 24 during a time period in which a large amount of BOG is generated as described above.

[0032] Thus, when a change in internal pressure of the LNG tank 21, which may be caused in a case in which the BOG compressor 24 is stopped, is predicted to specify a stoppable time period of the BOG compressor 24, whether or not the DR can be implemented can be determined without hindering stable operation of the LNG receiving facility 2.

[0033] Now, an example of a method of calculating the stoppable time period of the BOG compressor 24 is described.

[0034] When a stop time of the BOG compressor 24 (pressure storage start time for the BOG in the BOG compressor 24) is represented by t_1 and an operation restart time of the BOG compressor 24 (pressure storage end time for the BOG) is represented by t_2 , a stop time period of the BOG compressor 24 is represented by $(t_2 - t_1)$.

[0035] When an LNG delivery flow rate from the LNG tank 21 is represented by F [m^3/h] and a liquid level of the LNG in the LNG tank 21 at the time t_1 is represented by L_1 [m], a liquid level L_2 [m] at the time t_2 is expressed by Expression (Math. 1) (in which ID [m] represents an inner diameter of the LNG tank 21).

[Math. 1]

$$L_2 = L_1 - F \cdot (t_2 - t_1) \div \pi \left(\frac{ID}{2} \right)^2$$

[0036] Further, when a gas-phase volume of the LNG tank 21 at the time t_1 is represented by V_1 [m^3], a gas-phase volume V_2 [m^3] at the time t_2 is expressed by Expression (Math. 2).

[Math. 2]

$$V_2 = V_1 + F \cdot (t_2 - t_1)$$

[0037] Further, a quantity of heat input from the outside, for example, an outside air or a heater (not shown) for prevention of freezing of a ground, to the LNG tank 21 is represented by Q_{tank} [J/h], a quantity of heat input from the LNG pump 211 is represented by Q_{pump} [J/h], and a quantity of heat input from other facilities is represented by Q_{etc} [J/h], each being represented on a unit time basis, a generation amount W_{bog} [kg/h] of BOG per unit time in the LNG tank 21 is expressed by Expression (Math. 3) (in which λ represents evaporation latent heat [J/kg] of the LNG).

[Math. 3]

$$W_{\text{bog}} = (Q_{\text{tank}} + Q_{\text{pump}} + Q_{\text{etc}}) \div \lambda$$

[0038] Still further, the pressure in the LNG tank 21 at the time t_1 is represented by p_1 [kPaG], the pressure in the

LNG tank 21 at the time t2 is represented by p2 [kPaG], and densities of the BOG at the respective pressures are represented by ρ1 [kg/m³] and ρ2 [kg/m³], respectively.

[0039] When a temperature in the LNG tank 21 is constant and the BOG is not extracted from the LNG tank 21, a mass balance is calculated based on the amount of BOG generated in the LNG tank 21 during the stop time period (t2-t1) and a change in volume on a gas-phase side in the LNG tank 21. As a result, Expression (Math. 4) is obtained.

[Math. 4]

$$(\rho_2 \cdot V_2 - \rho_1 \cdot V_1) = W_{\text{bog}} \cdot (t_2 - t_1)$$

[0040] Then, when V1 and V2 are eliminated from (Math. 4) based on the relationships of (Math. 1) and (Math. 2) to rearrange (Math. 4), Expression (Math. 5) is obtained.

[Math. 5]

$$(t_2 - t_1) = -\left(\frac{\rho_2}{\rho_1}\right) \cdot \pi \left(\frac{ID}{2}\right)^2 \cdot (L_2 - L_1) \div W_{\text{bog}}$$

[0041] The LNG tank 21 includes a liquid level gauge. Thus, a pressure change in the LNG tank 21 in the above-mentioned time period can be obtained based only on a change in liquid level height of the LNG in the LNG tank 21 from the liquid level at the time t1 to the liquid level at the time t2. As described above, the densities ρ1 and ρ2 of the BOG are uniquely determined in accordance with the pressures p1 and p2 at the respective times. Thus, the stop time period is calculated with (Math. 5) based on the pressure change in the LNG tank 21.

[0042] Thus, the upper limit value of the operating pressure of the LNG tank 21 is set to the pressure ρ2 in the LNG tank 21 at the time t2 (density ρ2 of the BOG at this time). As a result, the stoppable time period (t2-t1) for maintaining the pressure in the LNG tank 21 to a pressure less than the upper limit value of the operating pressure under a condition in which the BOG compressor 24 is in a stopped state can be specified. As described above, the change (L2-L1) in liquid level of the LNG during the stoppable time period can be predicted from (Math 1).

[0043] In the LNG receiving facility 2 of this example, whether or not the DR is implemented can be determined based on the above-mentioned result of calculation of the stoppable time period of the BOG compressor 24.

[0044] Now, specific contents at the time of implementation of the DR in the LNG receiving facility 2 are described with reference to FIG. 3.

[0045] In the LNG receiving facility 2, at a time of a normal operation, for example, the LNG pumps 211 and 22, the ORVs231, and the BOG compressor 24 are operated, and the product gas is sent with requested calorific value and flow rate to the demander 3 (P11). At this time, operation data (I12: for example, the delivery flow rate F, the liquid level L1 of the LNG in the LNG tank 21, and an outside temperature and a calorific value supplied from a heater (not shown), which are to be used for calculation of the quantity of heat Qtank) that is needed for the above-mentioned calculations of the stoppable time period with (Math. 1) to (Math. 5) is continuously acquired.

[0046] Further, in the LNG receiving facility 2, in anticipation of reception of a request for implementation of the DR (reduction in power consumption) based on, for example, a change in outside temperature or prediction of supply and demand of electric power, which may be announced by the power transmission and distribution business operator 11, examination of reduction in power consumption can be started (examination start step).

[0047] In this case, calculations of (Math. 3) and (Math. 5) are performed based on, for example, the acquired operation data and the prediction of the change in temperature (prediction of Qtank) so that a change in pressure in the LNG tank 21 from a pressure at a time at which the implementation of the DR is anticipated is predicted (P13). Then, the stoppable time period of the BOG compressor 24 is calculated based on the change in pressure (P14).

[0048] The above-mentioned calculations may be performed offline by an operator with use of a computer, or may be automatically performed with use of an operation control system such as a distributed control system (DCS) for the LNG receiving facility 2. The prediction of the change in pressure in the LNG tank 21 and the calculation of the stoppable time period of the BOG compressor 24 correspond to a stoppable time period calculation step of this example.

[0049] Further, for the vaporizers, the number of ORVs 231 and the number of SMVs 232, which are currently operating, and consumed power of the seawater pump are calculated (P21).

[0050] When it is determined on the power transmission and distribution business operator 11 side that the implementation of the DR is required, a preliminary notice relating to the reduction in power consumption (I01) is given from the resource aggregator 12. In FIG. 3, illustration of the resource aggregator 12 is omitted. The notice contains information

about, for example, an implementation time period of the DR (reduction time period) and demanded reduction in electric power.

[0051] When the above-mentioned preliminary notice is received, the implementation time period of the DR and the stoppable time period that has been previously calculated are compared to each other so as to examine whether or not the BOG compressor 24 can be stopped (P15: stoppability determination step). For example, when the stoppable time period of the BOG compressor 24 is longer than the implementation time period of the DR, it is determined that the DR can be implemented.

[0052] Then, when a request for reduction in power consumption (I02) is received from the resource aggregator 12 after the preliminary notice is made, it is determined that the BOG compressor 24 is actually stopped (P16), and an operation stop operation is executed (P17: gas compression unit stopping step).

[0053] Further, further reducible electric power is grasped based on a result of grasp of operating conditions of the ORVs 231 and the SMVs 232 (all the ORVs 231 are operating during the normal operation) (P22). Then, adjustment is performed with the resource aggregator 12 because, for example, the power consumption can be further reduced. After the adjustment, when the request for reduction in power consumption (I02) is received, the vaporizers are switched from the ORVs 231 to the SMVs 232 (P23: vaporizer switching step).

[0054] Meanwhile, as a result of examination of whether or not the BOG compressor 24 can be stopped (P15) after the reception of the preliminary notice, when it is found out that, for example, the stoppable time period of the BOG compressor 24 is shorter than the implementation time period of the DR, it is determined that the stoppable time period that meets the request from the resource aggregator 12 cannot be ensured.

[0055] In this case, when there is plenty of time from the reception of the preliminary notice to the reception of the actual request for reduction in power consumption, operation adjustment for reducing the pressure in the LNG tank 21 may be performed. As contents of the operation adjustment, the following is exemplified. Specifically, a mixing ratio of the BOG to the product gas is increased to increase the amount of extraction of the BOG from the LNG tank 21. The demander 3 is requested to increase the amount of reception of the product gas to thereby increase the amount of feeding of the LNG so as to lower the liquid level of the LNG.

[0056] Thus, when it is determined in the stage of examination of stoppability (P15) that it is difficult to stop the BOG compressor 24, a target pressure at a time of implementation of the operation adjustment is calculated so as to be lower than the pressure in the LNG tank 21 at the time when the determination is made (P31: target pressure setting step). The target pressure is set so that the stoppable time period of the BOG compressor 24, which is calculated by the above-mentioned method, becomes longer than the implementation time period of the DR.

[0057] After that, when it is determined that the operation adjustment for reducing the internal pressure of the LNG tank 21 to the target pressure can be implemented (P32), the operation adjustment is performed (P33: pressure reduction step). Then, the prediction of a change in internal pressure of the LNG tank 21 (P13) and the calculation of the stoppable time period of the BOG compressor 24 (P14) are performed, and the examination of the stoppability (P15) is performed again. When the internal pressure of the LNG tank 21 reaches the target pressure due to the operation adjustment, it is determined that the BOG compressor 24 can be stopped under this state. Thus, after the request for the reduction in power consumption (I02) is received from the resource aggregator 12, it is determined that the BOG compressor 24 is stopped (P16). Then, the operation stop operation is performed (P17).

[0058] Meanwhile, as described above, when an LNG reception time period from the LNG tanker 4, in which the amount of generation of the BOG becomes several times that during the normal operation, and the implementation time period of the DR overlap, there is a high possibility that the BOG compressor 24 cannot be stopped even after the above-mentioned operation adjustment is performed. Thus, in this case, the examination of whether or not the BOG compressor 24 can be stopped may be omitted, and determination of prioritization of continuation of the operation of the BOG compressor 24 (continuation determination step) may be performed.

[0059] The overlap between the reception time period for the LNG and the implementation time period of the DR may be avoided by adjusting a ship allocation schedule of the LNG tanker 4 so that the LNG is received on Saturday, Sunday, or a holiday on which there is a low possibility that the request for the implementation of the DR may be issued.

[0060] According to the method of operating the LNG receiving facility 2 according to this embodiment, the following effects are obtained. The stoppable time period of the BOG compressor 24, in which the BOG is extracted from the LNG tank 21, is calculated, and whether or not the BOG compressor 24 can be stopped is determined based on the result of calculation. Thus, the DR can be implemented without hindering the stable operation of the LNG receiving facility 2.

[0061] In the example described with reference to FIG. 3, in anticipation of the implementation of the DR, the prediction of a change in internal pressure of the LNG tank 21 (P13) and the calculation of the stoppable time period of the BOG compressor 24 (P14) are performed in advance. Then, in response to the preliminary notice of the implementation of the DR, whether or not the BOG compressor 24 can be stopped is examined.

[0062] However, the order of examination may be suitably changed. For example, when there is sufficient time from the reception of the request for the reduction in power consumption (I02) to the execution of the request (stop of the BOG compressor 24), the prediction of a change in internal pressure of the LNG tank 21 and the calculation of the

stoppable time period of the BOG compressor 24 (P13 and P14: stoppable time period calculation step), and the examination of stoppability (P15: stoppability determination step) may be performed after the request for the reduction is received.

5 Reference Signs List

[0063]

11	power transmission and distribution business operator
10 12	resource aggregator
13	consumer
2	LNG receiving facility
21	LNG tank
211, 22	LNG pump
15 231	open rack vaporizer (ORV)
232	submerged-combustion vaporizer (SMV)
24	BOG compressor
3	demand

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Claims

1. A method of operating a liquefied natural gas receiving facility,
the liquefied natural gas receiving facility including:

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a storage tank configured to store a liquefied natural gas received from an outside;
vaporizers configured to vaporize the liquefied natural gas delivered from the storage tank so as to send the liquefied natural gas in a gaseous state; and
a gas compression unit to be driven by an electric motor, which is configured to boost pressure of a boil off gas generated in the storage tank so as to mix the boil off gas boosted in pressure with the natural gas vaporized in the vaporizers,

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the method comprising:

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an examination start step of starting examination of reduction in power consumption upon receiving a request for the reduction in power consumption, which contains information about a reduction time period, or in anticipation of reception of the request;
a stoppable time period calculation step of predicting a change in internal pressure of the storage tank, which is caused when the gas compression unit is stopped, and calculating a stoppable time period of the gas compression unit; and
a stoppability determination step of determining whether the gas compression unit is stoppable based on a result of comparison between the reduction time period and the stoppable time period of the gas compression unit.

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2. The method of operating a liquefied natural gas receiving facility according to claim 1, further comprising a gas compression unit stopping step of, when determination is made in the stoppability determination step that the gas compression unit is stoppable in the reduction time period, stopping the gas compression unit.

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3. The method of operating a liquefied natural gas receiving facility according to claim 2,
wherein the vaporizers include:

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a vaporizer for normal operation, which is configured to vaporize the liquefied natural gas with use of seawater supplied as a heat source through a seawater pump to be driven by an electric motor; and
a vaporizer for emergency operation, which is configured to vaporize the liquefied natural gas with use of heat of combustion of the natural gas as a heat source, and

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wherein the method further comprises a vaporizer switching step to be executed in addition to execution of the gas compression unit stopping step, the vaporizer switching step of switching the vaporizer for normal operation to the vaporizer for emergency operation and vaporizing the liquefied natural gas.

4. The method of operating a liquefied natural gas receiving facility according to claim 1, wherein, in the stoppable time period calculation step, the change in internal pressure is predicted based on a change in gas-phase volume, which is caused along with the delivery of the liquefied natural gas from the storage tank, and a boil off gas amount generated in the storage tank.
5. The method of operating a liquefied natural gas receiving facility according to claim 4, wherein the boil off gas amount generated in the storage tank is calculated based on a quantity of heat input to the storage tank.
6. The method of operating a liquefied natural gas receiving facility according to claim 1, wherein, in the stoppable time period calculation step, a time period in which a prediction value of the change in internal pressure of the storage tank is less than an upper limit value of an operating pressure, which is set for the storage tank, is set as the stoppable time period.
7. The method of operating a liquefied natural gas receiving facility according to claim 1, further comprising a continuation determination step of, when the reduction time period overlaps a time period in which the liquefied natural gas is received by the storage tank from the outside, determining prioritization of continuation of the operation of the gas compression unit.
8. The method of operating a liquefied natural gas receiving facility according to claim 1, further comprising:
 - a target pressure setting step of, when a result of determination in the stoppability determination step is negative, setting a target pressure lower than a pressure in the storage tank at a time of execution of the stoppability determination step so as to reduce power consumption; and
 - a pressure reduction step of reducing the internal pressure of the storage tank to the target pressure, wherein the stoppability determination step is executed again after the pressure reduction step.

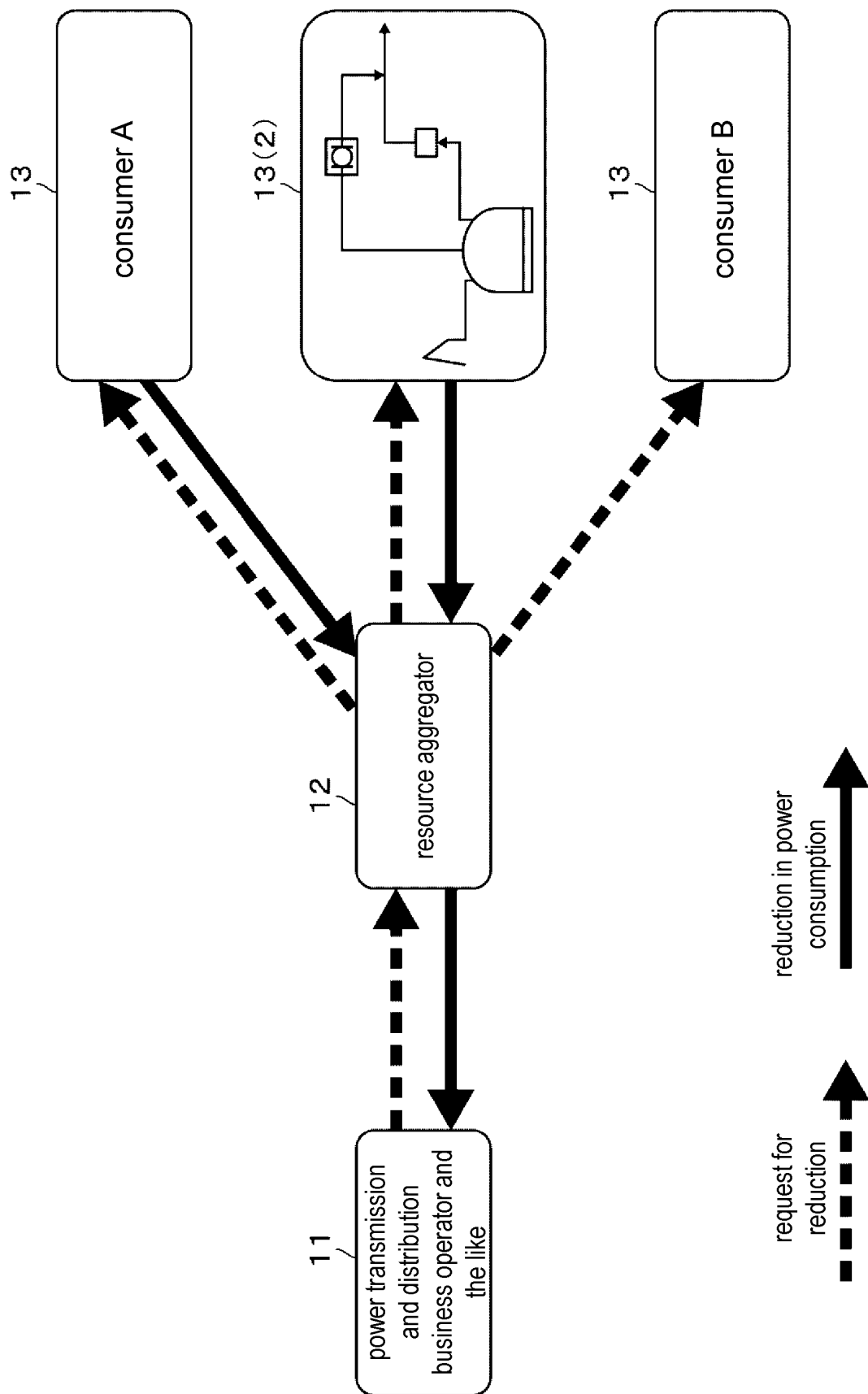


FIG. 1

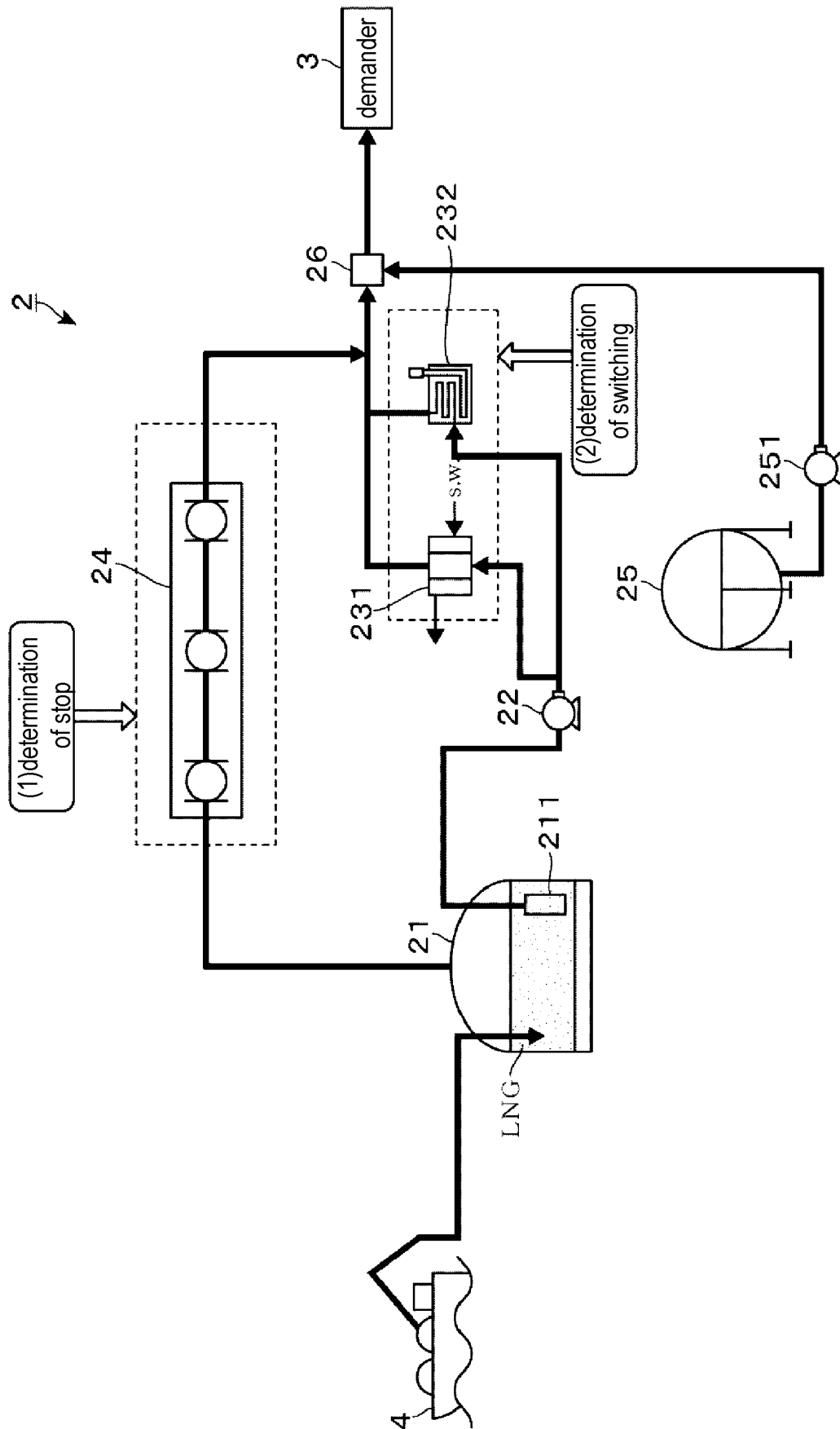


FIG. 2

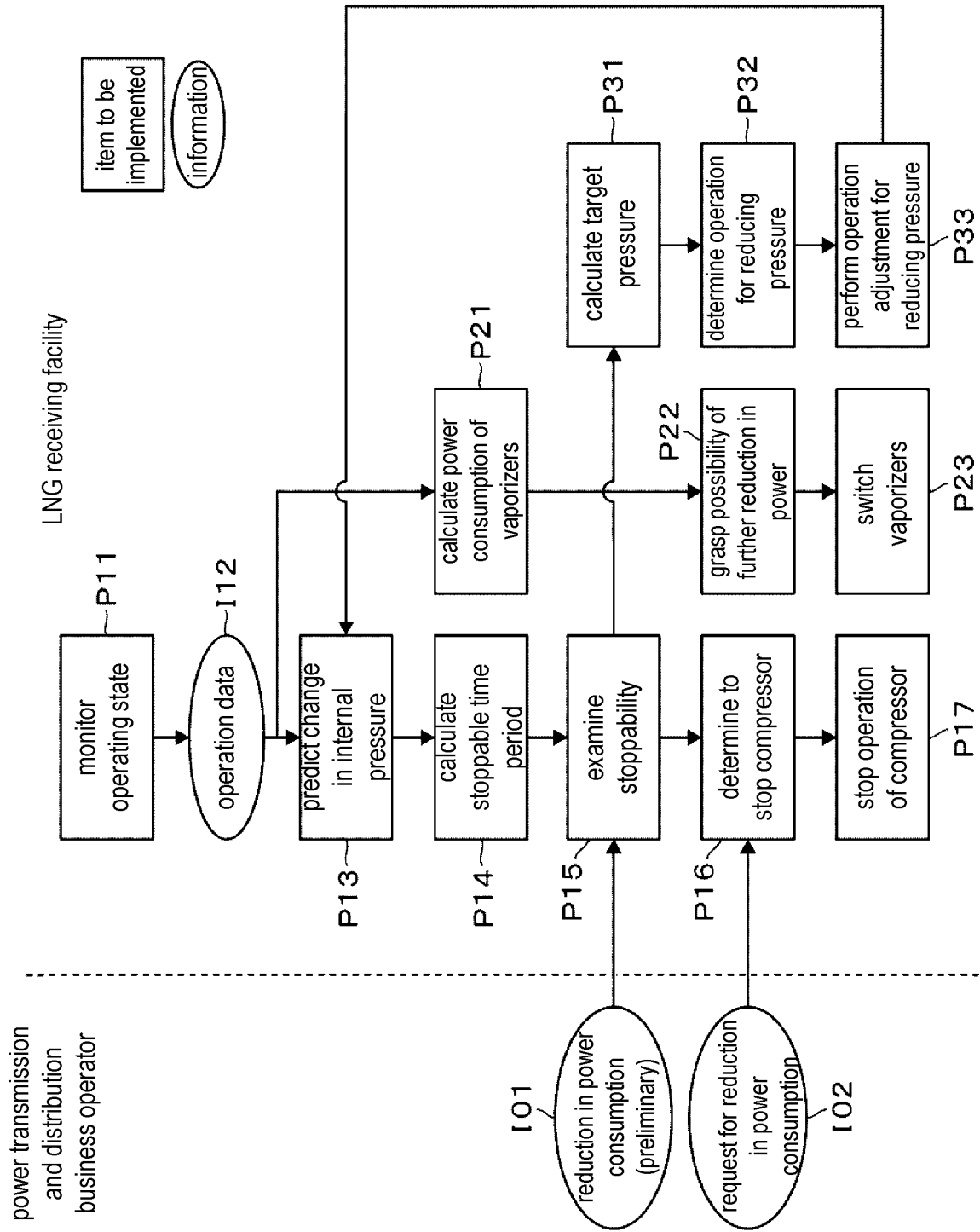


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/034255

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F17C13/00 (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)

Int. Cl. F17C13/00

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2018-112218 A (IHI CORP.) 19 July 2018 (Family: none)	1-8
A	JP 2016-177399 A (HITACHI, LTD.) 06 October 2016 (Family: none)	1-8
A	JP 2010-154617 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 08 July 2010 (Family: none)	1-8
A	JP 2010-246306 A (NTT FACILITIES, INC.) 28 October 2010 (Family: none)	1-8



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

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"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

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"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
26.10.2018Date of mailing of the international search report
06.11.2018Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6343372 B [0007]
- JP 2018112218 A [0007]