Claims

[Claim 1] A computer-implemented method for assisting the management of a vessel for transporting liquefied gas, the vessel comprising at least one tank configured to contain liquefied gas and a vapor phase treatment system, the vapor phase treatment system being capable of sending boil-off gas exiting the tank to a propulsion engine of the vessel and to a gas combustion unit on board the vessel, the method comprising:

– providing an initial state of the tank, said initial state of the tank comprising an initial pressure of the gas phase contained in the tank and an initial temperature of the liquid phase contained in the tank;

– providing a forecast path of the vessel;

– determining, on the basis of weather forecasts, at least one environmental parameter of the vessel along said forecast path;

– determining a speed curve of the vessel along said forecast path;

– generating a tank management scenario defining an evolution of the pressure of the gas phase contained in the tank during said forecast path, and, on the basis of the tank management scenario thus generated:

a) estimating a curve of an indicative quantity, the indicative quantity being indicative of the operation of the propulsion engine along said forecast path, as a function of said speed curve of the vessel and of said at least one environmental parameter;

b) estimating a curve of the amount of boil-off gas generated in the tank along said forecast path;

c) estimating, on the basis of said curve of the indicative quantity and of said curve of the amount of boil-off gas generated, a curve of the amount of gas to be extracted from the tank and a curve of the amount of boil-off gas to be burned in the gas combustion unit; and

d) computing a cost function that at least depends on a total amount of boil-off gas generated in the tank along said forecast path; and

– displaying to a user the tank management scenario as a function of the computed cost function.

[Claim 2] The method as claimed in claim 1, wherein the vapor phase treatment system is further capable of extracting a portion of the liquid phase contained in the tank and of evaporating this portion in order to send it to the propulsion engine.

[Claim 3] The method as claimed in any one of claims 1 to 2, wherein the indicative quantity is the power required to be output from the propulsion engine along said forecast path.

[Claim 4] The method as claimed in any one of claims 1 to 3, wherein multiple tank management scenarios are generated, with steps a) to d) being carried out for each tank management scenario, and wherein at least one of said tank management scenarios is displayed to the user as a function of the computed cost function for said tank management scenario.

[Claim 5] The method as claimed in claim 4, wherein, before displaying at least one of said tank management scenarios to the user, said tank management scenarios are iteratively regenerated a number of times by a first evolutionary algorithm using the cost function as a first objective function.

[Claim 6] The method as claimed in any one of claims 1 to 5, wherein said forecast path comprises path steps each defined by two waypoints and a heading to be followed between said two waypoints, and wherein, in step a), said curve of the indicative quantity is estimated as a function of said headings to be followed, of said speed curve of the vessel and of said at least one environmental parameter.

[Claim 7] The method as claimed in any one of claims 1 to 6, wherein said speed curve of the vessel is determined from said forecast path and from said at least one environmental parameter by a second evolutionary algorithm using a second objective function that depends on said total amount of boil-off gas generated in the tank along said forecast path and on a difference between a required time of arrival at the destination and an estimated time of arrival at the destination.

[Claim 8] The method as claimed in any one of claims 1 to 7, wherein providing a forecast path of the vessel comprises providing an offloading pressure and/or an offloading temperature required by an offloading terminal at the destination of the vessel, and wherein, in step d), the cost function further depends on a difference between the pressure of the gas phase contained in the tank at the end of said forecast path and said offloading pressure and/or a difference between the temperature of the liquid phase contained in the tank at the end of said forecast path and said offloading temperature.

[Claim 9] The method as claimed in any one of claims 1 to 8, wherein, in step a), said curve of the indicative quantity is estimated using a first statistical model, the first statistical model being capable of estimating said indicative quantity at least as a function of a vessel speed setpoint and of said at least one environmental parameter, and the first statistical model being trained by a supervised machine learning method.

[Claim 10] The method as claimed in any one of claims 1 to 9, wherein the aforementioned step b) involving estimating a curve of the amount of boil-off gas generated in the tank along said forecast path comprises estimating a first amount of boil-off gas generated in the tank as a function of a current pressure of the gas phase contained in the tank

and of a current temperature of the liquid phase contained in the vessel and estimating a second amount of boil-off gas generated in the tank as a function of a current pressure of the gas phase contained in the tank and of said at least one environmental parameter.

[Claim 11] The method as claimed in claim 10, wherein the second amount of boil-off gas generated in the tank is estimated using a second statistical model, the second statistical model being trained by a supervised machine learning method.

[Claim 12] The method as claimed in any one of claims 1 to 11, wherein the initial state comprises an initial composition of the liquefied gas contained in the tank, and wherein step b) involving estimating a curve of the amount of boil-off gas generated in the tank along said forecast path further comprises estimating a composition of the boil-off gas generated in the tank.

[Claim 13] The method as claimed in any one of claims 1 to 12, wherein the environmental parameter comprises at least one from among a current direction, a current speed, a wind speed, a wind direction, an average wave height, a wave direction, and a wave period.

[Claim 14] The method as claimed in any one of claims 1 to 13, wherein the vapor phase treatment system further comprises a reliquefaction plant capable of reliquefying boil-off gas exiting the tank and of returning the boil-off gas thus re-liquefied to the tank, and wherein the aforementioned step c) comprises estimating, on the basis of said curve of the indicative quantity and of said curve of the amount of boil-off gas generated, a curve of the amount of gas to be extracted from the tank, a curve of the amount of boil-off gas to be burned in the gas combustion unit, and a curve of the amount of boil-off gas to be sent to the reliquefaction plant.

[Claim 15] The method as claimed in any one of claims 1 to 14, wherein the vapor phase treatment system further comprises a sub-cooler capable of sub-cooling a portion of the liquid phase contained in the tank and of returning the portion thus sub-cooled to the tank, and wherein the aforementioned step c) comprises estimating, on the basis of said curve of the indicative quantity and of said curve of the amount of boil-off gas generated, a curve of the amount of gas to be extracted from the tank, a curve of the amount of boil-off gas to be burned in the gas combustion unit, and a curve of the amount of liquid phase to be extracted from the tank and to be sent to the sub-cooler.

[Claim 16] The method as claimed in any one of claims 1 to 15, wherein the steps of the method as claimed in claim 1 are repeated at fixed intervals and/or upon receipt of new weather forecasts.

[Claim 17] A system for assisting the management of a vessel for transporting liquefied gas, the vessel comprising at least one tank configured to contain liquefied gas and a

vapor phase treatment system, the vapor phase treatment system being capable of sending boil-off gas exiting the tank to a propulsion engine of the vessel and to a gas combustion unit on board the vessel, the system comprising:

– an acquisition unit configured to acquire an initial state of the tank and a forecast path of the vessel, said initial state of the tank comprising an initial pressure of the gas phase contained in the tank and an initial temperature of the liquid phase contained in the tank;

– a first communication unit configured to obtain weather forecasts from a weather forecast provider; and

– a computation unit configured to: on the basis of the weather forecasts obtained by the first communication unit, determine at least one environmental parameter of the vessel along said forecast path; determine a speed curve of the vessel along said forecast path; generate a tank management scenario defining an evolution in the pressure of the gas phase contained in the tank along said forecast path, and, on the basis of the tank management scenario thus generated, configured to:

a) estimate a curve of an indicative quantity, the indicative quantity being indicative of the operation of the propulsion engine along said forecast path, as a function of said speed curve of the vessel and of said at least one environmental parameter;

b) estimate a curve of the amount of boil-off gas generated in the tank along said forecast path;

c) estimate, on the basis of said curve of the indicative quantity and of said curve of the amount of boil-off gas generated, a curve of the amount of gas to be extracted from the vessel and a curve of the amount of boil-off gas to be burned in the gas combustion unit;

d) compute a cost function that at least depends on a total amount of boil-off gas generated in the tank along said forecast path; and comprising

– a display unit configured to display to a user the tank management scenario as a function of the computed cost function.

[Claim 18] The system as claimed in claim 17, wherein the vapor phase treatment system is further capable of extracting a portion of the liquid phase contained in the tank and of evaporating this portion in order to send it to the propulsion engine.

[Claim 19] The system as claimed in any one of claims 17 to 18, wherein the indicative quantity is the power required to be output from the propulsion engine along said forecast path.

[Claim 20] The system as claimed in any one of claims 17 to 19, wherein said forecast path comprises path steps each defined by two waypoints and a heading to be followed between said two waypoints, and wherein the computation unit is configured to: a)

estimate said curve of the indicative quantity as a function of said headings to be followed, of said speed curve of the vessel and of said at least one environmental parameter.

[Claim 21] The system as claimed in any one of claims 17 to 20, wherein the acquisition unit and the display unit are on board the vessel, the first communication unit and the computation unit are located in a ground station, and wherein the system further comprises a second communication unit configured to connect the acquisition unit and the computation unit.