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(54) **SYSTEM AND METHOD FOR PRODUCING A LIQUEFIED HYDROCARBON STREAM AND METHOD OF OPERATING A COMPRESSOR**

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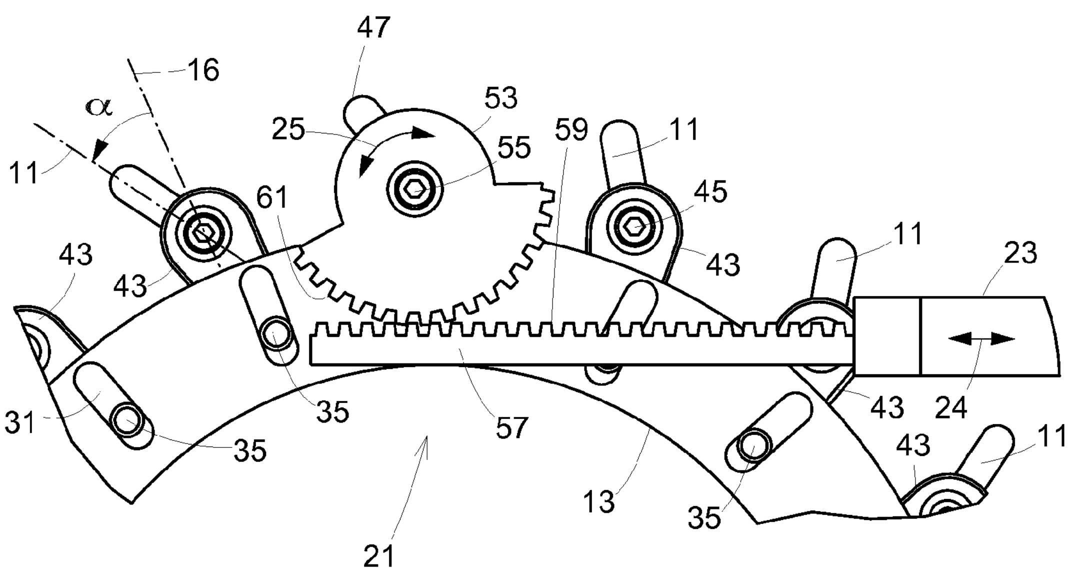
(57) **ABSTRACT**

At least part of a fluid is compressed in a compressor driven by an electric motor. The compressor has variable inlet guide vanes of which an angle can be adjusted. The electric motor is powered using a power supply network, and a signal representative of a condition of the power supply network is monitored. From the signal, it is automatically determined whether additional load shedding is needed, by comparing the signal to a predetermined criterion. The variable inlet guide vanes angle is automatically adjusted when the criterion is satisfied and additional load shedding is needed. This automatically reduces the loading of the compressor. The compressor and the method of operating it may be employed as part of a system for producing a liquefied hydrocarbon stream and/or in the course of producing a liquefied hydrocarbon stream, in which case the compressor can be a refrigerant compressor and the fluid a refrigerant fluid.



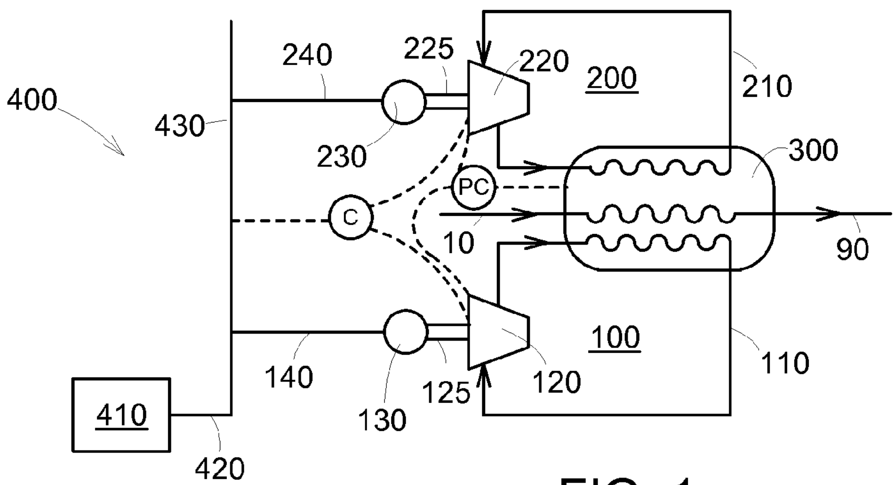

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FIG. 1

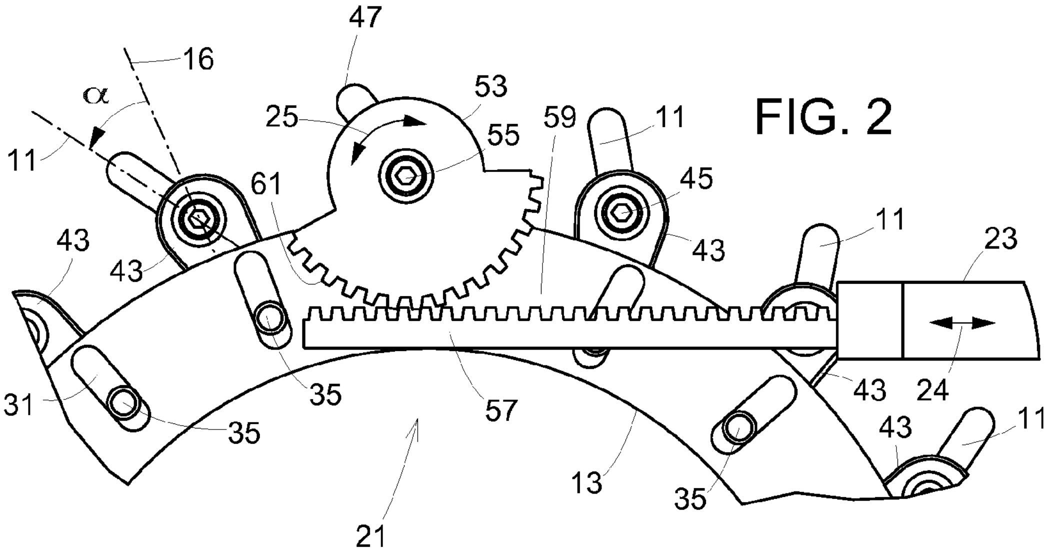
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FIG. 2

SYSTEM AND METHOD FOR PRODUCING A LIQUEFIED HYDROCARBON STREAM AND METHOD OF OPERATING A COMPRESSOR

[0001] In a first aspect, the present invention relates to a method of producing a liquefied hydrocarbon stream. In a second aspect, the present invention relates to a system for producing a liquefied hydrocarbon stream. In a further aspect, the present invention relates to a method of operating a compressor.

[0002] A common liquefied hydrocarbon stream in the industry is liquefied natural gas (LNG), which may be obtained by liquefying a natural gas stream. It is desirable to liquefy natural gas for a number of reasons. As an example, natural gas can be stored, and transported over long distances, more readily in the form of LNG than in gaseous form, because as LNG it occupies a smaller volume and does not need to be stored at a high pressure.

[0003] US pre-grant patent application publication No. 2010/0257895 describes an all electric LNG plant wherein LNG is produced, in which compressors in the form of refrigerant compressors are employed to refrigerate the natural gas. The refrigerant compressors are driven by electric motors. A power plant supplies the electrical power for these motors. The power plant contains a plurality of power generation units, each based on an electric generator driven by a gas or steam turbine.

[0004] If, for some reason, the available electrical power suddenly goes down, or is partially interrupted, the LNG production process will fail and it can take at least a number of hours before the refrigerant compressor(s) have started up again and before the LNG production process has regained it stability of operation.

[0005] This risk can be reduced by installing an over-capacity of power generation (based on the so-called N+1 principle) in the form of stand-by power generation units, or by operating a plurality of power generation units at less than full capacity (sometimes referred to as maintaining "spinning reserve"). These solutions have in common that failure of one generation unit can be afforded because, compared to the N power generation units minimally required to deliver the total power demand of the LNG plant, an additional power generation unit is provided in accordance with the N+1 principle.

[0006] US 2010/0257895 further proposes that in the event of the failure of a power generation unit in the power plant, the (rotational) speed of the compressor drive will preferably be lowered if a previously determined overall positive load reserve is smaller than the power which was being supplied by the power generation unit before its failure. According to the quadratic load characteristic curve of a turbine compressor, the power drawn from the electric motors reduces as the cube of the rotational speed. Only if the actual energy demand of the LNG plant is not covered even taking into account the reduction in the compressor drive speed, it is expedient to switch off at least one predetermined electrical consumer in the gas liquefaction plant.

[0007] One drawback of the load shedding solution proposed in US 2010/0257895 is that the response time for load shedding to take effect is limited by the total rotational inertia of rotating parts of the motors, compressors and drive shafts. Another drawback is that the solution of US 2010/0257895 requires the compressor(s) to be driven by variable-speed motors.

[0008] In a first aspect, the present invention provides a method of producing a liquefied hydrocarbon stream, comprising:

[0009] circulating a refrigerant fluid through a refrigerant circuit, comprising compressing at least part of the refrigerant fluid in a refrigerant compressor driven by an electric motor wherein the refrigerant compressor comprises variable inlet guide vanes of which an angle compared to a reference position can be adjusted;

[0010] removing heat from an initially vaporous hydrocarbon stream thereby condensing at least part of the initially vaporous hydrocarbon stream to form the liquefied hydrocarbon stream, said removing of heat comprising heat exchanging at least said part of the initially vaporous hydrocarbon stream against at least part of the refrigerant fluid circulating through the refrigerant circuit;

[0011] powering the electric motor using a power supply network;

[0012] monitoring a signal representative of a condition of the power supply network;

[0013] automatically determining from the signal whether additional load shedding is needed by comparing the signal to a predetermined criterion;

[0014] automatically adjusting the variable inlet guide vanes angle thereby reducing the loading of the refrigerant compressor when the criterion is satisfied and additional load shedding is needed.

[0015] In a further aspect, the invention provides a system for producing a liquefied hydrocarbon stream, comprising:

[0016] a refrigerant circuit arranged to circulate a refrigerant fluid, comprising a refrigerant compressor for compressing at least part of the refrigerant fluid and an electric motor engaged to the refrigerant compressor to drive the refrigerant compressor wherein the refrigerant compressor comprises variable inlet guide vanes having an adjustable angle compared to a reference position;

[0017] a heat exchanger train comprising at least one heat exchanger, said heat exchanger train arranged to remove heat from an initially vaporous hydrocarbon stream thereby condensing at least part of the initially vaporous hydrocarbon stream to form the liquefied hydrocarbon stream, said least one heat exchanger arranged to accommodate at least said part of the initially vaporous hydrocarbon stream and at least part of the refrigerant fluid circulating through the refrigerant circuit in a mutual heat exchanging relationship;

[0018] a power supply network connected to the electric motor for powering the electric motor;

[0019] a load shedding controller arranged to monitor a signal representative of a condition of the power supply network, to automatically determine from the signal whether additional load shedding is needed by comparing the signal to a predetermined criterion, and, when the criterion is satisfied and additional load shedding is needed, to adjust the variable inlet guide vanes angle to a position wherein the refrigerant compressor is unloaded relative to the loading in a previous condition whereby the variable inlet guide vanes angle was in a previous position when the criterion was not satisfied.

[0020] In still another aspect, the invention provides a method of operating a compressor, comprising:

[0021] compressing at least part of a fluid in a compressor driven by an electric motor, wherein the compressor comprises variable inlet guide vanes of which an angle can be adjusted;

[0022] powering the electric motor using a power supply network;

[0023] monitoring a signal representative of a condition of the power supply network;

[0024] automatically determining from the signal if additional load shedding is needed by comparing the signal to a predetermined criterion;

[0025] automatically adjusting the variable inlet guide vanes angle thereby reducing the loading of the compressor when additional load shedding is needed.

[0026] The present invention will now be further illustrated by way of example, and with reference to the accompanying non-limiting drawings, in which:

[0027] FIG. **1** schematically shows a system for producing a liquefied hydrocarbon stream; and

[0028] FIG. **2** schematically shows an illustrative non-limiting example of an embodiment of variable inlet guide vanes in a centrifugal compressor.

[0029] For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. The same reference numbers refer to similar components, streams or lines.

[0030] The present disclosure describes methods and systems for producing a liquefied hydrocarbon stream. In the course of producing the liquefied hydrocarbon stream, a compressor is employed which is driven by an electric motor. At least part of a fluid is compressed in the compressor. The compressor has variable inlet guide vanes of which an angle can be adjusted. The electric motor is powered using a power supply network, and a signal representative of a condition of the power supply network is monitored. From the signal, it is automatically determined whether additional load shedding is needed, by comparing the signal to a predetermined criterion. The variable inlet guide vanes angle are automatically adjusted when the criterion is satisfied and additional load shedding is needed, thereby automatically reducing the loading of the compressor.

[0031] By adjusting the variable inlet guide vanes angle, the power demand can be reduced without relying on reducing the motor speed. Therefore, the presently proposed method of load shedding can be employed irrespective of whether a variable speed electric drive is used or a fixed speed electric drive.

[0032] Moreover, the inertia of the rotating mass such as rotating parts of the motor, the compressor and the drive shaft, does not influence the response time of a load shedding action. Inlet guide vanes have much less inertia than the rotating parts of the motor/compressor system, and therefore it is envisaged that the response time associated with adjusting the variable inlet guide vanes can be much lower.

[0033] For instance, the compressor is unloaded by adjusting the variable inlet guide vanes angle when the monitored signal indicates that the available power drops below a predetermined value. The condition of the power supply network represented by the signal may thus represent power available on the power supply network relative to power being consumed, whereby the predetermined criterion is satisfied when the available power, according to the monitored signal, drops below a predetermined value.

[0034] This way the power supply network can be protected by quickly unloading the compressor thereby imposing a quick relief of the power being demanded from the power supply network.

[0035] If the predetermined criterion is not satisfied, no additional load shedding is needed.

[0036] In one group of embodiments the signal representative of the condition of the power supply network is representative of a network frequency at which the power supply network operates. The need for additional load shedding can be inferred from such a signal if the network frequency deviates from a pre-determined nominal network frequency. Typically, if the actual network frequency is lower than the nominal network frequency load shedding may be needed in order to reduce the power demand on the network which helps to bring the actual network frequency back to the nominal network frequency. Automatically determining from the signal whether additional load shedding is needed may comprise comparing the actual network frequency to a pre-determined nominal network frequency. The predetermined criterion to determine whether additional load shedding is needed may include the nominal network frequence and the criterion is satisfied when the actual network frequence drops below the predetermined nominal network frequency.

[0037] In preferred embodiments, the compressor is provided in the form of a refrigerant compressor, whereby the fluid is a refrigerant fluid, such as may be employed in a system and/or process for producing a liquefied hydrocarbon stream. Suitably, the compressor is driven only by the electric motor.

[0038] The proposed load shedding method can also be used to prevent overloading that could result from an increase in ambient temperature. This may be useful particularly if the compressor is provided in the form of a refrigerant compressor employed for compressing at least part of a refrigerant fluid, as may be done in the course of operating a process of producing as liquefied hydrocarbon stream. An increase in ambient temperature generally increases the power demand for liquefying the hydrocarbon stream. In addition, if the power supply network is powered via one or more gas turbines, the available power will reduce as a result of the increase in ambient temperature.

[0039] The proposed load shedding method can be used in connection with compressors relying on so-called "island-mode" power generation, where the power supply network is powered by a dedicated power plant, as well as those powered by imported power such as imported power from a domestic grid or from an industrial grid to which other consumers of power are connected as well.

[0040] Provided that the compressor comprises variable inlet guide vanes of which an angle can be adjusted, implementation of the proposed load shedding method does not require significant adaptations of equipment. Implementation may be achieved by changing the existing control system which is typically already in place for controlling the inlet guide vane settings, or by adding a dedicated control system.

[0041] FIG. **1** illustrates the method of operating the compressor in the context of a method and system for producing a liquefied hydrocarbon stream. However, the teachings provided herein below regarding the operation of the compressor are not necessarily restricted to, or limited to, embodiments wherein the compressor is a refrigerant compressor and/or wherein the fluid is a refrigerant fluid.

[0042] The system illustrated in FIG. **1** employs at least one refrigerant circuit, including a first refrigerant circuit **100** arranged to circulate a refrigerant fluid **110**. Each of the at least one refrigerant circuits comprises a compressor in the form of a refrigerant compressor **120**, for compressing at least part of the refrigerant fluid **110** being circulated in the refrigerant circuit **100**. Each refrigerant compressor is engaged with an electric motor **130**, typically via a mechanical drive shaft **125** extending between the respective refrigerant compressor **120** and the electric motor **130** to drive the rotor of the respective refrigerant compressor **120** into rotation.

[0043] The electric motor **130** is connected to a power supply network **400**, for powering the electric motor **130**. The power supply network comprises a power source, typically in the form of a power plant **410** and a distribution network **420** connected to the power source. The power plant can be of the "island-mode" type, which is a dedicated power plant for powering the hydrocarbon liquefaction facility, or it can be an external power source from which power is imported into the facility. The distribution network **420** may be connected to a power busbar **430**, arranged to feed power to the at least one electric motor **130** via a power feed line **140**.

[0044] In the embodiment of FIG. **1**, the at least one refrigerant circuit comprises an optional second refrigerant circuit **200** as well, to circulate a second refrigerant fluid **210**. It comprises a second refrigerant compressor **220**; a second electric motor **230**; a second power feed line **240**; and a second mechanical drive shaft **125** all similarly interrelated as described above with reference to the first refrigerant circuit **100**.

[0045] The system depicted in FIG. **1** further comprises a heat exchanger train **300**. The heat exchanger train **300** is very schematically shown, as many different types of such heat exchanger trains are known in the art. The heat exchanger train **300** is arranged to remove heat from an initially vaporous hydrocarbon stream **10**, thereby condensing at least part of the initially vaporous hydrocarbon stream **10** to form a liquefied hydrocarbon stream **90**. The heat exchanger train typically comprises at least one heat exchanger that is arranged to accommodate at least said part of the initially vaporous hydrocarbon stream **10** in a mutual heat exchanging relationship with at least part of the refrigerant fluid **110** circulating through the refrigerant circuit **100**.

[0046] The compressor(s) may be of any type that is provided with variable inlet guide vanes, including axial compressors (for example the AN **200** axial compressor manufactured by General Electric) and centrifugal compressors.

[0047] Inlet guide vanes are often installed on commercially available refrigerant compressors to increase efficiency and to extend the operating envelope. Inlet guide vanes are typically installed on the first compression stage, but for instance in case of integrally geared compressors, with multiple compressor stages, inlet guide vanes can also be installed on one or more subsequent stages such as the second stage.

[0048] Inlet guide vanes are typically provided in the form of radially positioned aerofoils in the vapour flow of the compressor. Suitably the inlet guide vanes are positioned inside the suction duct. Generally and under normal operating conditions such inlet guide vanes serve to guide the refrigerant vapour into the subsequent compression stage at the most efficient direction onto the vanes or impellers of the subsequent compression stage.

[0049] Variable inlet guide vanes, such as may be employed in the context of the present invention, are normally rotatable about their mounting axes. Under normal operating conditions, different refrigerant entry speeds can be accommodated by rotating the variable inlet guide vanes into different positions. Rotation may be imparted on the variable inlet guide vanes by a vane adjustment mechanism coupled to an actuator.

[0050] The invention is expressly not limited to any particular type of inlet guidvane geometry and or vane adjustment mechanism. There are various suitable ways for acting on the vanes, including rotating ring concepts, lever concepts, hydraulic pistons concepts, all acting on the variable inlet guide vanes. Examples of variable inlet guide vanes and possible mechanisms for adjusting their angle are shown in for instance US patent application publication 2010/0172745 and U.S. Pat. No. 7,520,716. In these examples the vapour flows generally inwardly towards the rotating axis of the compressor. US patent application publication 2010/0329898 shows an example wherein the vapour generally flows axially, in the direction along the rotating axis. US patent application publications 2010/0172745 and 2010/0329898, and U.S. Pat. No. 7,520,716 are incorporated in the present disclosure by reference.

[0051] An embodiment of variable inlet guide vanes of a centrifugal compressor, derived from US patent application publication 2010/0172745, is shown in FIG. **2** as an illustrative non-limiting example. It comprises a vane adjustment mechanism employing a rotating ring **13** provided with a plurality of elongated slots **31**, and inlet guide vanes **11** positioned around a circumference of the rotating ring **13**. The inlet guide vanes **11** are pivotably attached to a base plate (not shown, in the interest of clarity), such that each one of the inlet guide vanes **11** can pivot around a shaft **45**. The inlet guide vanes **11** are each coupled to an end of one of a plurality of lever arms **43** by the shaft **45**. Each lever arm **43** is provided with an outwardly protruding pin **35** in a direction perpendicular to a plane of rotation of the lever arms **43** around their shafts **45**. Each pin **35** is configured to be positioned within one of the elongated slots **31**. As rotating ring **13** rotates relative to the base plate, each inlet guide vane **11** is rotated by the same amount.

[0052] Still referring to FIG. **2**, the vane adjustment mechanism also includes a rack and pinion drive mechanism **21** configured to drive one of the plurality of inlet guide vanes **11**, thereby creating a drive vane **47**. The rack and pinion drive mechanism includes a pinion **53** coupled to an elongated shaft **55** of the drive vane **47**, which replaces the shaft **45**, and a rack **57**. The rack **57** includes a plurality of teeth **59** that is configured to engage with a plurality of teeth **61** on the pinion **53**, thereby operationally coupling the rack **57** to the pinion **53**. An end of the rack **57** is coupled to a drive shaft **23**, which may be actuated by for instance hydraulic cylinder (not shown).

[0053] The drive shaft **23** is arranged to impart a linear motion **24** to the rack **57**, which is converted to rotational motion **25** in the pinion **53** thereby rotating drive vane **47** relative to the base plate. Drive vane **47** transfers torque to the rotating ring **13** due to the positioning of each pin **35** on each lever arm **43** within the associate elongated slot **31** of the rotating ring **13** with which the pin **35** interacts. The torque is thereby transmitted to the remaining inlet guide vanes **11**, as shown in FIG. **2**, whereby the respective inlet guide vanes **11** are caused to synchronously change their angular position by the same amount. This way the variable inlet guide vanes angle α compared to a reference position **16** can be adjusted. In FIG. **2**, the radial position is taken to be the reference position **16** as an example, but any suitable reference position can be selected.

[0054] Referring again to FIG. **1**, the system is further provided with a load shedding controller C. The load shedding controller C is arranged to monitor a signal that is representative of the available power on the power supply network relative to the power being consumed, and to adjust the variable inlet guide vanes angle when the available power, as monitored, drops below a predetermined value. In such a case, the variable inlet guide vanes angle is adjusted to a position wherein the refrigerant compressor is unloaded relative to the loading in a previous condition whereby the variable inlet guide vanes angle was in a previous position. To this end, the controller C may interact with the actuator of the compressor **120**.

[0055] A suitable signal to monitor is the network frequency. When an AC power supply network is in stable operation it operates at a (pre-determined) nominal frequency. The network frequency, which may be defined as the frequency of the overall system associated with the power network (including the active electric generators and all the running loads that consume power), generally depends directly on the amount of power that the generators can deliver to the system compared to the power being demanded for consumption. Gradual or sudden downward changes in generation capacity result in frequency decline. The network frequency is thus a good indicator for the need of load shedding, which is particularly suitable in combination with island mode power generation. Preferably, the controller C interacts with the actuator of the compressor **120** so as to halt the drop in network frequency.

[0056] Particularly when operating on imported power, the signal may suitably be an external signal, generated by the power provider or one of the power providers providing power to the network, to request load shedding.

[0057] Thus, the variable inlet guide vanes angle are preferably adjusted whereby the refrigerant compressor is unloaded by a portion of the original load that is equal to or greater than the power generation deficiency. Herewith the balance between power generation and the power demand will be restored where after the power network can continue its stable operation.

[0058] The system may further comprise a process controller PC for controlling the production of the liquefied hydrocarbon stream **90**. It may advantageously be arranged to maintain the variable inlet guide vanes at an optimized target angle, to optimize one or both of efficiency and operating envelope of the refrigerant compressor **120** when the available power as monitored is at or above the predetermined value.

[0059] The load shedding controller C can be a separate dedicated controller unit or it can be integrated with another controller, for instance one that is arranged to control also other aspects of the system, or it can be a hybrid controller whereby selected parts of the load shedding controller C are provided as a separate controller and other parts are provided integrated with the other controller. In one example, the other controller can be the process controller PC.

[0060] The system described above may be operated as follows.

[0061] The refrigerant fluid **110** is circulated through the refrigerant circuit **100**. In the course of this circulating, at least part of the refrigerant fluid **100** is compressed in the refrigerant compressor **120** to form a compressed refrigerant. The refrigerant compressor **120** is driven by the electric motor **130**, which typically imparts a rotational motion to the mechanical drive shaft **125** about its longitudinal axis. The electric motor **130** is powered using power from the power supply network **400**.

[0062] The compressed refrigerant is passed to the heat exchanger train **300**, where it is typically allowed to expand to a lower pressure and evaporate by receiving heat from at least an initially vaporous hydrocarbon stream **10**. In many cases, but this is not a requirement for every type of heat exchanger train **300**, the compressed refrigerant is condensed and preferably sub-cooled before it is allowed to expand to said lower pressure. The evaporated refrigerant is led back from the heat exchanger train **300** to the refrigerant compressor **120**, to be recompressed. This completes one cycle in the refrigerant circuit **100**. Simultaneously during the cycle, heat is removed from the initially vaporous hydrocarbon stream **10** by at least part of the evaporating refrigerant, by heat exchanging at least said part of the initially vaporous hydrocarbon stream **10** against said at least part of the refrigerant fluid circulating through the refrigerant circuit **100**. Ultimately at least part of the initially vaporous hydrocarbon stream **10** is condensed as a result of removing heat from it by the refrigerant fluid **120** and optional second and further refrigerant fluids, to form the liquefied hydrocarbon stream **90**.

[0063] Under normal stable operation, the variable inlet guide vanes are set manually by the operator or automated by the process controller PC and/or a compressor anti surge controller. The variable inlet guide vanes are set at a selected angle, for instance to achieve a desired operating window.

[0064] The available power on the power supply network **400** is monitored, and the variable inlet guide vanes can be maintained at the selected angle or moved to another selected angle as desired as long as the available power as monitored is at or above a predetermined value. In preferred embodiments of operation, the variable inlet guide vanes are maintained at an optimized target angle to optimize one or both of efficiency and operating envelope of the refrigerant compressor as long as the available power as monitored is at or above the predetermined value.

[0065] However, when the available power as monitored drops below the predetermined value, the load shedding controller reacts by adjusting the variable inlet guide vanes angle, thereby unloading the refrigerant compressor **120**. This can be done by quickly changing the angle to a position different from the selected angle. If the selected angle was at the optimized target angle, which would be the case in preferred embodiments of operation, the unloading of the refrigerant compressor **120** is achieved by deliberately changing the variable inlet guide vanes angle away from the optimized target angle.

[0066] Normally, the load demand by the refrigerant compressor is reduced by closing the variable inlet guide vanes which in accordance with convention in the art corresponds to moving the position of the variable inlet guide vanes to increasingly negative angles, whereby 0° corresponds to the optimized target angle.

[0067] The heat exchanger train **300** in the present specification has been depicted very schematically. It can represent any suitable hydrocarbon liquefaction process, in particular any natural gas liquefaction process producing liquefied natural gas, and the invention is not limited by the specific choice of heat exchanger train. Examples of suitable heat exchanger trains are derivable from single refrigerant cycle processes (usually single mixed refrigerant—SMR—processes, such as PRICO described in the paper "LNG Production on floating platforms" by K R Johnsen and P Christiansen, presented at Gastech 1998 (Dubai), but also possible is a single component refrigerant such as for instance the BHP-cLNG process also described in the afore-mentioned paper by Johnsen and Christiansen); double refrigerant cycle processes (for instance the much applied Propane-Mixed-Refrigerant process, often abbreviated C3MR, such as described in for instance U.S. Pat. No. 4,404,008, or for instance double mixed refrigerant—DMR—processes of which an example is described in U.S. Pat. No. 6,658,891, or for instance two-cycle processes wherein each refrigerant cycle contains a single component refrigerant); and processes based on three or more compressor trains for three or more refrigeration cycles (an example is described in U.S. Pat. No. 7,114,351).

[0068] Other examples of suitable heat exchanger trains are described in: U.S. Pat. No. 5,832,745 (Shell SMR); U.S. Pat. No. 6,295,833; U.S. Pat. No. 5,657,643 (both are variants of Black and Veatch SMR); U.S. Pat. No. 6,370,910 (Shell DMR). Another suitable example of DMR is the so-called Axens LIQUEFIN process, such as described in for instance the paper entitled "LIQUEFIN: AN INNOVATIVE PROCESS TO REDUCE LNG COSTS" by P-Y Martin et al, presented at the 22nd World Gas Conference in Tokyo, Japan (2003). Other suitable three-cycle heat exchanger trains include for example U.S. Pat. No. 6,962,060; WO 2008/020044; U.S. Pat. No. 7,127,914; DE3521060A1; U.S. Pat. No. 5,669,234 (commercially known as optimized cascade process); U.S. Pat. No. 6,253,574 (commercially known as mixed fluid cascade process); U.S. Pat. No. 6,308,531; US application publication 2008/0141711; Mark J. Roberts et al "Large capacity single train AP-X™ Hybrid LNG Process", Gastech 2002, Doha, Qatar (13-16 Oct. 2002). These suggestions are provided to demonstrate wide applicability of the invention, and are not intended to be an exclusive and/or exhaustive list of possibilities. Not all examples listed above employ electric motors as refrigerant compressor drivers. It will be clear that any drivers other than electric motors can be replaced for an electric motor to be suitable for application in the context of the present invention.

[0069] The initially vaporous hydrocarbon stream **10** to be refrigerated, and ultimately preferably liquefied, may be derived from any suitable gas stream to be refrigerated and optionally liquefied. An often used example is a natural gas stream, obtained from natural gas or petroleum reservoirs or coal beds. As an alternative the initially vaporous hydrocarbon stream **10** may also be obtained from another source, including as an example a synthetic source such as a Fischer-Tropsch process.

[0070] When the initially vaporous hydrocarbon stream **10** is a natural gas stream, it is usually comprised substantially of methane. Preferably the gaseous hydrocarbon stream **10** comprises at least 50 mol % methane, more preferably at least 80 mol % methane.

[0071] Depending on the source, natural gas may contain varying amounts of hydrocarbons heavier than methane such as in particular ethane, propane and the butanes, and possibly lesser amounts of pentanes and aromatic hydrocarbons. The composition varies depending upon the type and location of the gas.

[0072] Conventionally, the hydrocarbons heavier than methane are removed as far as needed to produce a liquefied hydrocarbon product stream in accordance with a desired specification. Hydrocarbons heavier than butanes (C4) are removed as far as efficiently possible from the natural gas prior to any significant cooling for several reasons, such as having different freezing or liquefaction temperatures that may cause them to block parts of a methane liquefaction plant.

[0073] The natural gas may also contain non-hydrocarbons such as H_2O, N_2, CO_2, Hg, H_2S and other sulphur compounds, and the like. Thus, if desired, the initially vaporous hydrocarbon stream **10** comprising the natural gas may be (pre-)treated before or during being refrigerated. This (pre-) treatment may comprise reduction and/or removal of undesired components such as CO_2 and H_2S or other steps such as early cooling, pre-pressurizing or the like. As these steps are well known to the person skilled in the art, their mechanisms are not further discussed here.

[0074] In preferred embodiments disclosed herein, the initially vaporous hydrocarbon stream **10** comprises natural gas, whereby the liquefied hydrocarbon stream **90** is a liquefied natural gas stream.

[0075] The compressor, such as the refrigerant compressor, used herein may be exclusively driven by the electric motor, meaning the electric motor is the only driver driving the compressor.

[0076] The person skilled in the art will understand that the present invention can be advantageously applied in combination with other load shedding techniques and/or power plant designs, in particular including one or more of the elements as described in US pre-grant patent application publication No. 2010/0257895; U.S. Pat. No. 7,114,351; Gastech 2005 paper "All Electric Driven Refrigeration Compressors in LNG Plants Offer Advantages" by Fritz Kleiner and Steve Kaufmann. For instance, in case the presently proposed system and method for producing a liquefied hydrocarbon stream comprises two or more refrigerant compressors in parallel operation (each compressing a portion of the total amount of refrigerant flow) one or more of the compressors can be tripped while keeping the remainder in operation. This may be particularly considered if an extreme adjusting of the inlet guide vanes is required and/or operation under significant reduced load is anticipated for a prolonged period of time.

[0077] The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

1. A method of producing a liquefied hydrocarbon stream, comprising:

circulating a refrigerant fluid through a refrigerant circuit, comprising compressing at least part of the refrigerant fluid in a refrigerant compressor driven by an electric motor wherein the refrigerant compressor comprises variable inlet guide vanes of which an angle compared to a reference position can be adjusted;

removing heat from an initially vaporous hydrocarbon stream thereby condensing at least part of the initially vaporous hydrocarbon stream to form the liquefied hydrocarbon stream, said removing heat comprising heat exchanging at least said part of the initially vapor-

ous hydrocarbon stream against at least part of the refrigerant fluid circulating through the refrigerant circuit;
powering the electric motor using a power supply network;
monitoring a signal representative of a condition of the power supply network;
automatically determining from the signal whether additional load shedding is needed by comparing the signal to a predetermined criterion; and,
automatically adjusting the variable inlet guide vanes angle thereby reducing the loading of the refrigerant compressor when the criterion is satisfied and additional load shedding is needed.

2. The method of claim **1**, further comprising maintaining the variable inlet guide vanes at an optimized target angle to optimize one or both of efficiency and operating envelope of the refrigerant compressor when the criterion is not satisfied.

3. The method of claim **2**, wherein said adjusting the variable inlet guide vanes angle comprises deliberately changing the variable inlet guide vanes angle away from the optimized target angle.

4. The method of claim **1**, wherein said condition of the power supply network represents power available on the power supply network relative to power being consumed, and wherein the predetermined criterion is satisfied when the available power, according to the monitored signal, drops below a predetermined value.

5. The method of claim **1**, wherein the power supply network operates at a network frequency and wherein the signal representative of the condition of the power supply network represents the network frequency at which the power supply network operates.

6. The method of claim **1**, wherein the initially vaporous hydrocarbon stream comprises natural gas and wherein the liquefied hydrocarbon stream is a liquefied natural gas stream.

7. System for producing a liquefied hydrocarbon stream, comprising:
a refrigerant circuit arranged to circulate a refrigerant fluid, comprising a refrigerant compressor for compressing at least part of the refrigerant fluid and an electric motor engaged to the refrigerant compressor to drive the refrigerant compressor wherein the refrigerant compressor comprises variable inlet guide vanes having an adjustable angle compared to a reference position;
a heat exchanger train comprising at least one heat exchanger, said heat exchanger train arranged to remove heat from an initially vaporous hydrocarbon stream thereby condensing at least part of the initially vaporous hydrocarbon stream to form the liquefied hydrocarbon stream, said least one heat exchanger arranged to accommodate at least said part of the initially vaporous hydrocarbon stream and at least part of the refrigerant fluid circulating through the refrigerant circuit in a mutual heat exchanging relationship;
a power supply network connected to the electric motor for powering the electric motor; and,
a load shedding controller arranged to monitor a signal representative of a condition of the power supply network, to automatically determine from the signal whether additional load shedding is needed by comparing the signal to a predetermined criterion, and, when the criterion is satisfied and additional load shedding is needed, to adjust the variable inlet guide vanes angle to a position wherein the refrigerant compressor is unloaded relative to the loading in a previous condition whereby the variable inlet guide vanes angle was in a previous position when the criterion was not satisfied.

8. The system of claim **7**, further comprising a process controller arranged to maintain the variable inlet guide vanes at an optimized target angle to optimize one or both of efficiency and operating envelope of the refrigerant compressor when the criterion is not satisfied.

9. The system of claim **7**, wherein said condition of the power supply network represents power available on the power supply network relative to power being consumed, and wherein the predetermined criterion is satisfied when the available power, according to the monitored signal, drops below a predetermined value.

10. The system of claim **7**, wherein the power supply network operates at a network frequency and wherein the signal representative of the condition of the power supply network represents the network frequency at which the power supply network operates and wherein the predetermined criterion is satisfied when the network frequency drops below a predetermined nominal network frequency.

11. Method of operating a compressor, comprising:
compressing at least part of a fluid in a compressor driven by an electric motor, wherein the compressor comprises variable inlet guide vanes of which an angle can be adjusted;
powering the electric motor using a power supply network;
monitoring a signal representative of a condition of the power supply network;
automatically determining from the signal if additional load shedding is needed by comparing the signal to a predetermined criterion; and,
automatically adjusting the variable inlet guide vanes angle thereby reducing the loading of the compressor when the criterion is satisfied and additional load shedding is needed.

12. The method of claim **11**, further comprising maintaining the variable inlet guide vanes at an optimized target angle to optimize one or both of efficiency and operating envelope of the compressor when the criterion is not satisfied.

13. The method of claim **12**, wherein said adjusting of the variable inlet guide vanes angle comprises deliberately changing the variable inlet guide vanes angle away from the optimized target angle.

14. The method of claim **11**, wherein said condition of the power supply network represents power available on the power supply network relative to power being consumed, and wherein the predetermined criterion is satisfied when the available power, according to the monitored signal, drops below a predetermined value.

15. The method of claim **11**, wherein the power supply network operates at a network frequency and wherein the signal representative of the condition of the power supply network represents the network frequency at which the power supply network operates and wherein the predetermined criterion is satisfied when the network frequency drops below a pre-determined nominal network frequency.

16. The method of claim **11**, wherein the compressor is a refrigerant compressor, whereby the fluid is a refrigerant fluid.

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