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(54) **COMPRESSOR SURGE DETECTION SYSTEM AND METHOD**

(57) A compressor surge detection system (1) for a refrigerating apparatus (100), comprises: a sensing system, configured for detecting a monitoring parameter representative of a saturating evaporating temperature of the refrigerating fluid at an inlet (I) of the compressor; a processing unit, programmed to process the monitoring parameter for deriving a diagnostic parameter, representative of an oscillatory behavior for the monitoring parameter and for generating an alert signal in response to the diagnostic parameter.

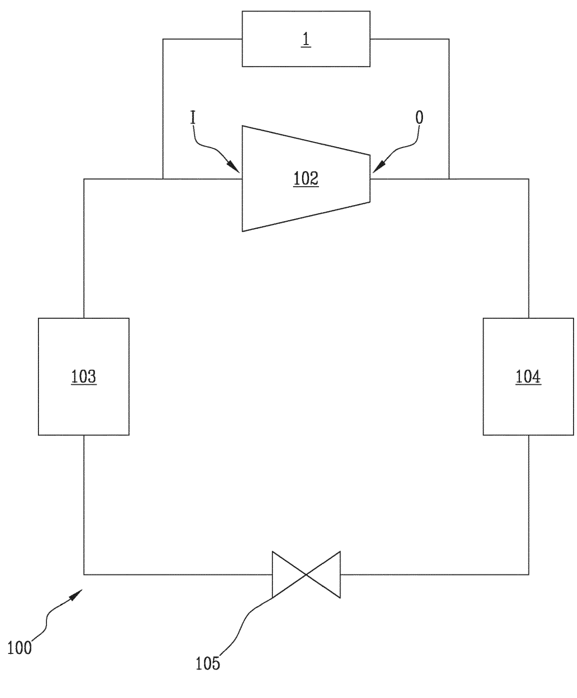

Fig.1

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Description

[0001] This invention relates to a compressor surge detection system and method.

[0002] Compressors are widely used in heating, ventilation and air conditioning systems (HVAC) for increasing the pressure of a gas by reducing its volume.

[0003] Axial and centrifugal compressors are among the most common types of compressors used in industrial facilities. The compressor is generally part of a system that delivers compressed gas for a variety of applications. The proper operation of a compressor depends on instrumentation and control devices which provide information about the compressor operating conditions and allow the compressor to be started or stopped. These devices maintain the values of process variables such as compressor discharge pressure in order to keep the compressor operation stable. Generally, for a given discharge pressure a compressor has a certain minimum flowrate, below which the compressor becomes unstable. A decrease in flowrate below the minimum value can cause a series of momentary reversals of flow through the compressor from the outlet to the inlet. This situation is called "surge." In other words, surge happens when, under certain operating conditions, the pressure of the gas exiting the discharge line of the compressor is unable to overcome that of the downstream unit, causing a drop in the mass flow rate and, consequently, a return of gas to the suction part of the compressor. Surge is an undesirable phenomenon that can occur in axial and centrifugal compressors and usually results in violent fluctuations in discharge pressure and extreme variations in electrical current of an electric motor which is used as a driver.

[0004] Surging can cause the compressor to overheat to the point at which the maximum allowable temperature is exceeded. Also, the occurrence of gas backflow in the compressor due to the surge can destroy the compressor's seals, bearings, and other rotating elements. Therefore, detecting the onset of the surge and preventing it, is of high importance. Moreover, in case the onset of surge is detected, it is essential to implement countermeasures in order to protect the compressor.

[0005] In this context, patent documents CN107829969A, CN112492884A, US4562531A and US10436208B2 describe known systems and methods for compressor surge detection and surge protection.

[0006] However, these solutions have some disadvantages and can be improved. Typically, conventional methods of surge detection are based on the measurements of different operational values of the compressor such as the suction temperature which is measured by a probe placed at the compressor inlet or the value of the electrical current drawn by the motor of the compressor. Consequently, actuating means of these systems change the operating conditions of the compressor (such as flow rate or pressure) in response to the sensed values in order to exit the surge condition. However, measuring these values allows to detect the presence of surge when it is already happening and with a delay compared to the triggering of the phenomenon. Therefore, it is not possible to detect when the surge phenomenon is about to happen in a compressor.

[0007] Recent technologies allow a measurement of the frequency of different variables in order to detect the surge phenomenon. For example, patent document US4399548A describes a compressor surge counter having an accelerometer to monitor the vibrations of the compressor in a pre-selected time frame. Said vibration output signal has an amplitude and frequency corresponding to the compressor vibration magnitude and frequency. This signal is then applied to a comparator which has a preselected amplitude threshold setting corresponding to a preselected change in amplitude within the pre-selected time frame to indicate the surge in the compressor.

[0008] Each time the comparator threshold is exceeded, an output driver circuit is activated to increment the counter. This patent document provides a solution to detect and count the actual number of surges a compressor experience, however, similar to other mentioned documents, this solution does not allow to detect the surge phenomenon before it is running.

[0009] Moreover, patent document US4686834A describes a compressor controller, aimed at avoiding surge.

[0010] Scope of the present invention is to overcome at least one of the aforementioned drawbacks.

[0011] This scope is achieved by the compressor surge detection system and method according to the appended claims.

[0012] According to an aspect of the present description, the present invention provides a compressor surge detection system for a refrigerating apparatus. The refrigerating apparatus comprises a compressor. The compressor is configured for increasing the pressure of a refrigerating fluid. The compressor has an inlet and an outlet. The compressor has also an electrical motor driven by an inverter. The refrigerating apparatus comprises an evaporator. The refrigerating apparatus comprises also a condenser.

[0013] The detection system comprises a sensing system. The sensing system is configured for detecting a monitoring parameter. In an example the monitoring parameter is representative of either an electrical current absorbed by the electrical motor of the compressor or a saturating evaporating temperature of the refrigerating fluid at the inlet of the compressor. In another example, the monitoring parameter may be representative of both the electrical current absorbed by the electrical motor of the compressor and the saturating evaporating temperature of the refrigerating fluid at the inlet of the compressor.

[0014] The detection system comprises a processing unit. The processing unit is connected to the sensing system. The processing unit is programmed to process the monitoring parameter for deriving a diagnostic parameter.

[0015] In an example the diagnostic parameter is representative of an oscillatory behavior for the monitoring parameter with a periodicity shorter than 20 seconds. The processing unit may be programmed for deriving an alert signal responsive to the diagnostic parameter.

[0016] This solution allows to detect an onset of the surge phenomenon in the compressor based on the oscillations of the monitoring parameter.

[0017] The processing unit is programmed for increasing the value of the diagnostic parameter responsive to increments of amplitude and frequency of the oscillations of the monitoring parameter.

[0018] Therefore, the value of the diagnostic parameter increases as the oscillations of the monitoring parameter increase. This solution allows to measure in a very empirical way the magnitude of the surge, by correlating the amplitude and frequency of the oscillations of the monitoring parameter to the diagnostic parameter. Therefore, it would be possible to detect the dynamics of surge onset by frequency estimation. The diagnostic parameter is a dimensionless parameter.

[0019] The processing unit is programmed for deriving a mean value for the monitoring parameter over a pre-established period of time. The processing unit may be programmed for setting the value of the monitoring parameter based on a difference between an actual detected value for the monitoring parameter and the mean value.

[0020] Furthermore, the processing unit is programmed for deriving the value of the diagnostic parameter in dependence of the number of zero-crossings of the monitoring parameter over a predetermined time window.

[0021] In an example the pre-established period of time is shorter than 50 seconds. The processing unit is programmed for refreshing the mean value with periodicity set to the pre-established period of time.

[0022] In an example the processing unit is programmed to increase the value of the diagnostic parameter responsive to the following conditions being both verified:

i) a zero-crossing of the monitoring parameter is detected over a predetermined time window;
ii) an amplitude of the monitoring parameter exceeds a predetermined value defining a tolerance value, in the predetermined time window.

[0023] The tolerance value represents the amplitude of the oscillations of the monitoring parameter which normally affect the measurement, and which are to be attributed to the noise. By using a tolerance in the measurements any noise inducing oscillation is filtered.

[0024] The processing unit is programmed to reset the diagnostic parameter to zero in case the amplitude of the monitoring parameter is detected to be lower than or equal to the tolerance value continually in the predetermined time window.

[0025] The processing unit is programmed to increase the value of the diagnostic parameter by an increment based on a comparison between the amplitude of the monitoring parameter in the predetermined time window and the tolerance value. In an example the predetermined time window is lower than 5 seconds.

[0026] The compressor may include an impeller. In an example the processing unit of the detection system is configured to generate a command signal to increase the speed of the impeller, in case the diagnostic parameter exceeds a first threshold value.

[0027] This solution allows to exit surge condition since as soon as the speed of the impeller increases the diagnostic parameter tends to zero. Therefore, it would be possible to avoid the surge state without stopping the compressor.

[0028] In an example the processing unit is configured to generate a command signal to shut the compressor down in case the diagnostic parameter exceeds a second threshold value. The second threshold is greater than the first threshold value.

[0029] This solution allows to avoid the surge phenomenon when there is not enough time to stop the oscillations of the monitoring parameter.

[0030] According to another aspect of the present description, the present invention provides a refrigerating apparatus. The refrigerating apparatus comprises a compressor for increasing the pressure of a refrigerating fluid.

[0031] The compressor has an inlet and an outlet. Moreover, the compressor has an electrical motor driven by an inverter.

[0032] The refrigerating apparatus has an evaporator. The refrigerating apparatus has also a condenser.

[0033] The refrigerating apparatus has a compressor surge detection system to detect surge phenomena in the compressor wherein the compressor surge detection system is according to the present description.

[0034] According to another aspect of the present description, the present invention provides a method for detection of compressor surge for a refrigerating apparatus. The method comprises a step of detecting a monitoring value (or monitoring parameter) by a sensing system. In an example the monitoring value is representative of either an electrical current absorbed by an electrical motor of a compressor of the refrigerating apparatus or a saturating evaporating temperature of a refrigerating fluid at an inlet of the compressor.

[0035] In another example, the monitoring value is representative of both the electrical current absorbed by the electrical motor of the compressor and the saturating evaporating temperature of the refrigerating fluid at the inlet of the compressor of the refrigerating apparatus.

[0036] The method comprises a step of sending the monitoring parameter from the sensing system to a processing unit.

[0037] The method comprises a step of processing the monitoring parameter for deriving a diagnostic parameter. The diagnostic parameter may be representative of an oscillatory behavior for the monitoring parameter with a periodicity shorter than 20 seconds. Moreover, the method may comprise a step of generating an alert signal responsive to the diagnostic parameter. This solution allows to detect an onset of the surge phenomenon in the compressor based on the oscillations of the monitoring parameter.

[0038] The method comprises a step of increasing the value of the diagnostic parameter responsive to increments of amplitude and frequency of the oscillations of the monitoring parameter.

[0039] Therefore, the value of the diagnostic parameter increases as the oscillations of the monitoring parameter increase. This solution allows to measure in a very empirical way the magnitude of the surge, by correlating the amplitude and frequency of the oscillations of the monitoring parameter to the diagnostic parameter. Therefore, it would be possible to detect the dynamics of surge onset by frequency estimation. The diagnostic parameter is a dimensionless parameter.

[0040] The method comprises a step of deriving a mean value for the monitoring parameter over a pre-established period of time. Moreover, the method may comprise a step of setting the value of the monitoring parameter based on a difference between an actual detected value for the monitoring parameter and the mean value.

[0041] The method comprises a step of deriving the value of the diagnostic parameter in dependence of the number of zero-crossings of the monitoring parameter over a predetermined time window.

[0042] The method comprises also a step of refreshing the mean value with periodicity set to the pre-established period of time.

[0043] In an example the method comprises a step of increasing the value of the diagnostic parameter responsive to the following conditions being both verified:

i) a zero-crossing of the monitoring parameter is detected over a predetermined time window;
ii) an amplitude of the monitoring parameter exceeds a predetermined value defining a tolerance value, in the predetermined time window.

[0044] The tolerance value represents the amplitude of the oscillations of the monitoring parameter which normally affect the measurement, and which are to be attributed to the noise. By using a tolerance in the measurements any noise inducing oscillation is filtered.

[0045] Moreover, the diagnostic parameter is reset to zero in case the amplitude of the monitoring parameter is detected to be lower than or equal to the tolerance value continually in the predetermined time window.

[0046] The method comprises a step of increasing the value of the diagnostic parameter by an increment based on a comparison between the amplitude of the monitoring parameter in the predetermined time window and the tolerance value.

[0047] In an example the method comprises a step of generating a command signal to increase the speed of an impeller of the compressor, in case the diagnostic parameter exceeds a first threshold value. Moreover, in an example the method comprises a step of generating a command signal to shut the compressor down in case the diagnostic parameter exceeds a second threshold value.

[0048] The second threshold is greater than the first threshold value.

[0049] This solution allows to exit surge condition since as soon as the speed of the impeller increases the diagnostic parameter tends to zero. Therefore, it would be possible to avoid the surge state without stopping the compressor and to avoid the surge phenomenon when there is not enough time to stop the oscillations of the monitoring parameter.

[0050] According to another aspect of the present description, the present invention provides a computer program wherein the computer program includes instructions to perform the steps of the method according to the present description when it is run on a processor.

[0051] This and other features of the invention will become more apparent from the following detailed description of a preferred, non-limiting example embodiment of it, with reference to the accompanying drawings, in which:

- figure 1 illustrates a block diagram of a refrigerating apparatus including a compressor surge detection system according to the present description;
- figure 2 illustrates a mean value of a monitoring parameter over a pre-established period of time and an oscillation signal of the monitoring parameter around the mean value;
- figure 3 illustrates the value of the monitoring parameter as a function of time.

[0052] With reference to the figures the compressor surge detection system for a refrigerating apparatus 100 according to the present invention is indicated by number 1. In the present description, the expression "refrigerating apparatus" refers to any apparatus that works in a heat pump and refrigeration cycle and utilizes a refrigerating fluid as working fluid. The refrigerating apparatus 100 comprises a compressor 102 for increasing the pressure of a refrigerating fluid. The compressor 102 may be of axial or centrifugal type. The compressor has an inlet I and an outlet O. The compressor 102 has also an electrical motor driven by an inverter (not shown). The refrigerating apparatus 100 comprises an evaporator 103. The evaporator 103 may provide the gas which is compressed by the compressor 102. The refrigerating apparatus comprises also a condenser 104. The refrigerating apparatus may comprise also an expansion valve 105.

[0053] The compressor surge detection system for a refrigerating apparatus (or detection system) 1 comprises a sensing system. The sensing system is configured for detecting a monitoring parameter. In an example the monitoring parameter is representative of either an electrical current absorbed by the electrical motor of the compressor or a saturating evaporating temperature of the refrigerating fluid at the inlet of the compressor. In an example, the monitoring parameter is representative of both the electrical current absorbed by the electrical motor of the compressor 102 and the saturating evaporating temperature of the refrigerating fluid at the inlet I of the compressor 102.

[0054] The sensing system may comprise a plurality of sensors. for example, the sensing system may comprise temperature sensors and/or current measuring sensors. The detection system comprises a processing unit. The processing unit is connected to the sensing system. The processing unit is programmed to process the monitoring parameter for deriving a diagnostic parameter. The diagnostic parameter may be representative of an oscillatory behavior for the monitoring parameter with a periodicity shorter than 20 seconds. Preferably the periodicity is shorter than 10 seconds. In the present description, the expression "oscillatory behavior" refers to a behavior in which a value has a repeated back and forth movement around an equilibrium or mean value in a short interval of time. The processing unit is programmed for deriving a mean value X_m for the monitoring parameter over a pre-established period of time.

[0055] Figure 3 shows an example of the oscillatory behavior of the monitoring parameter. As it can be observed the oscillations take place in a short time (roughly 10 seconds in the example of figure 3). It can be observed from figure 3 that, before the beginning of the oscillatory behavior (corresponding to point 21 :25:30 on the X axis) the value of the monitoring parameter does not deviate significantly from the mean value and an almost flat line is observed; however, after this point the graph shows oscillations where the value of the monitoring parameter deviates noticeably from the mean value with a high frequency. The oscillatory behavior is prior to a sharp increase in the value of the monitoring parameter. As it can be seen, during said oscillatory behavior, the graph of the monitoring value over time is a signal having a plurality of peaks with respect to the mean value, wherein the mean value corresponds to the almost flat line before the beginning of the oscillatory behavior. The peaks above and below the mean value may have different distances with respect to the mean value.

[0056] In an example, the pre-established period of time is shorter than 50 seconds. Moreover, the processing unit is programmed for refreshing the mean value with periodicity set to the pre-established period of time.

[0057] In an example the processing unit is configured for setting the value of the monitoring parameter based on a difference between an actual detected X_d value for the monitoring parameter and the mean value X_m-X_d.

[0058] In figure 2, oscillations of the monitoring parameter around the mean value (Xm) are illustrated. As explained above, the processing unit is configured for receiving the detected value of the monitoring parameter from the sensing unit and to obtain the difference between the actual detected value and the mean value of the monitoring parameter. Therefore, the points of the signal of figure 2 are the difference between the detected value and the mean value of the monitoring parameter over the pre-established period of time. The signal of the difference between the detected value and the mean value of the monitoring parameter is a function of time.

[0059] The processing unit is programmed for detecting zero-crossings of the monitoring parameter. The expression "zero-crossing" refers to a point where the signal related to the difference between the detected value and the mean value of the monitoring parameter Xd-Xm, crosses the mean value Xm.

[0060] In particular, the processing unit is programmed for deriving the value of the diagnostic parameter in dependence of the number of zero-crossings of the monitoring parameter over a pre-determined time window. In an example the pre-determined time window is shorter than 5 seconds. Preferably the pre-determined time window is 3 seconds.

[0061] In an example, the processing unit is programmed to increase the value of the diagnostic parameter when the zero crossing is detected over said predetermined time window and when an amplitude A of the monitoring parameter exceeds a predetermined tolerance value tol in the pre-determined time window. It is to be mentioned that the processing unit is configured to increase the value of the diagnostic parameter only when both the above-mentioned conditions are verified. The expression "amplitude" refers to the distance between the peaks of the signal of the monitoring parameter Xd-Xm from the mean value Xm. The tolerance value tol is an amplitude threshold below which the value of the diagnostic parameter is equal to zero.

[0062] In particular, the processing unit is programmed for increasing the value of the diagnostic parameter responsive to increments of amplitude A and frequency of the oscillations of the monitoring parameter.

[0063] Therefore, in case a zero-crossing is detected in the pre-determined time window and the amplitude A of the signal is greater than the value of the tolerance tol the processing unit is programmed for increasing the value of the diagnostic parameter.

[0064] The processing unit is programmed to reset the diagnostic parameter to zero in case the amplitude A of the monitoring parameter is detected to be lower than or equal to the tolerance tol value continually in the predetermined time window.

[0065] The processing unit is programmed to increase the value of the diagnostic parameter by an increment based on a comparison between the amplitude A of the monitoring parameter in the predetermined time window and the tolerance value tol.

[0066] In an example, as shown in figure 2, the processing unit is programmed for determining the amount of the diagnostic value over the predetermined time window and for resetting the diagnostic parameter to zero in case the amplitude A of the monitoring parameter is detected to be lower than or equal to the tolerance tol value continually in the predetermined time window. Moreover, the processing unit is programmed for increasing the value of the diagnostic parameter by adding a fixed amount thereto every time a zero-crossing is detected, and the amplitude A is greater than the tolerance tol. The fixed amount which is added to the diagnostic parameter is determined based on the amplitude A of the signal and how much the amplitude is greater with respect to the mean value Xm. In an example, the greater the amplitude A is, the greater the fixed amount and consequently the diagnostic parameter will be. In an example, a plurality of intervals is defined for the amplitude of the monitoring parameter A. A fixed amount is associated to each interval of the amplitude of the monitoring parameter. The intervals with higher amplitude have a greater fixed amount. A first interval of the plurality of intervals of amplitude of the monitoring parameter is defined between the mean value of the monitoring parameter plus the value of the tolerance Xm+tol and the mean value plus twice the value of the tolerance Xm+2tol. A second interval of the plurality of intervals of the amplitude of the monitoring parameter is defined between the mean value plus twice the value of the tolerance Xm+2tol and the mean value plus triple the value of the tolerance Xm+3tol. A third interval of the plurality of intervals of the amplitude of the monitoring parameter is defined between the mean value plus triple the value of the tolerance Xm+3tol and the mean value plus quadruple the value of the tolerance and so on. In an example the fixed amount is equal to 0 when the amplitude A is equal or less than the tolerance or the mean value of the monitoring parameter plus the value of the tolerance Xm+tol. The fixed amount is equal to 1 in the first interval (when the amplitude is greater than the mean value of the monitoring parameter plus the value of the tolerance Xm+tol but does not exceed the mean value plus twice the value of the tolerance Xm+2tol. The fixed amount is equal to 2 in the second interval (when the amplitude is greater than the mean value plus twice the value of the tolerance Xm+2tol but does not exceed the mean value plus triple the value of the tolerance Xm+3tol. The fixed amount is equal to 3 when the amplitude exceeds the mean value plus triple the value of the tolerance Xm+3tol. During the pre-established period of time, the number of zero-crossings of the monitoring parameter is detected and each time a zero-crossing is detected, and the amplitude A is greater than the tolerance tol the fixed amount, depending on the interval the amplitude of the monitoring parameter falls within, is added to the diagnostic parameter. As explained before, the diagnostic parameter is reset to zero in case the amplitude of the monitoring parameter is detected to be lower than or equal to the tolerance value continually in the predetermined time window. The diagnostic parameter is cumulative; therefore, the diagnostic parameter in each moment, along the preestablished period of time, is the sum of all previous fixed amounts, relative to altitudes of all previous zero-crossings of the monitoring parameter.

[0067] In an example the fixed amount equals to 1 if the amplitude A is greater than the value of the tolerance tol and less than the amount of the mean value plus the value of the tolerance Xm+tol. Moreover, the fixed amount equals to 2 if the amplitude A is greater than the amount of the mean value plus the value of the tolerance Xm+tol and less than the amount of the mean value plus twice the value of the tolerance Xm+2tol and so on. In an example, the processing unit is programmed for deriving an alert signal responsive to the diagnostic parameter. The compressor 102 may include an impeller. The impeller contains a rotating set of vanes that forces the refrigerating fluid to reach higher velocity, raises the energy of the refrigerating fluid and therefore, a pressure rise is obtained.

[0068] In an example, the processing unit of the detection system 1 is configured to generate a command signal to increase the speed of the impeller in case the diagnostic parameter exceeds a first threshold value.

[0069] Moreover, in an example, the processing unit is configured to generate a command signal to shut the compressor 102 down in case the diagnostic parameter exceeds a second threshold value. The second threshold is greater than the first threshold value.

[0070] In an example the processing unit is configured to generate the command signal to increase the speed of the impeller when the first threshold calculated for the electrical current absorbed by the electrical motor of the compressor and the first threshold calculated for the saturating evaporating temperature of the refrigerating fluid at the inlet is greater than 18.

[0071] In an example the processing unit is configured to generate the command signal to shut the compressor 102 down when the second threshold calculated for the electrical current absorbed by the electrical motor of the compressor and the second threshold calculated for the saturating evaporating temperature of the refrigerating fluid at the inlet is greater than 23.

[0072] According to an aspect of the present description, the present invention provides a refrigerating apparatus 100. The refrigerating apparatus comprises a compressor 102 for increasing the pressure of a refrigerating fluid. The compressor has an inlet I and an outlet O. The compressor 102 has also an electrical motor driven by an inverter. The refrigerating apparatus comprises an evaporator 103. The evaporator is configured to provide the compressor 102 with low pressure vapor. The refrigerating apparatus comprises also a condenser 104. The condenser 104 is downstream the compressor 102 and is configured to receive high pressure vapor and to provide high pressure liquid at its outlet. The refrigerating unit 100 comprises also an expansion valve 105. The expansion valve is configured to provide low pressure vapor and liquid.

[0073] The refrigerating apparatus 100 comprises a compressor surge detection system 1 configured to detect surge phenomena in the compressor 102. The compressor surge detection system 1 is according to the present description.

[0074] According to another aspect of the present description, the present invention provides a method for detection of compressor surge for a refrigerating apparatus 100.

[0075] The method comprises a step of detecting a monitoring value by a sensing system. In an example the monitoring value (or monitoring parameter) is representative of either an electrical current absorbed by an electrical motor of a compressor 102 of the refrigerating apparatus 100 or a saturating evaporating temperature of a refrigerating fluid at an inlet I of the compressor. In another example, the monitoring value is representative of both the electrical current absorbed by the electrical motor of the compressor 102 of the refrigerating apparatus 100 and the saturating evaporating temperature of the refrigerating fluid at the inlet I of the compressor

[0076] The method comprises a step of sending the monitoring parameter from the sensing system to a processing unit. The method comprises also a step of processing the monitoring parameter for deriving a diagnostic parameter. The diagnostic parameter may be representative of an oscillatory behavior for the monitoring parameter with a periodicity shorter than 20 seconds.

[0077] The method comprises a step of deriving a mean value Xm for the monitoring parameter over a pre-established period of time.

[0078] In an example, the pre-established period of time is shorter than 50 seconds. The method comprises a step of refreshing the mean value with periodicity set to the pre-established period of time.

[0079] The method comprises a step of setting the value of the monitoring parameter based on a difference between an actual detected value for the monitoring parameter Xd and the mean value Xm.

[0080] The method comprises a step of deriving the value of the diagnostic parameter in dependence of the number of zero-crossings of the monitoring parameter over a predetermined time window. In an example the pre-determined time window is shorter than 5 seconds. Preferably, the pre-determined time window is 3 seconds. In an example the method comprises a step of increasing the value of the diagnostic parameter responsive to the following conditions being both verified:

i) a zero-crossing of the monitoring parameter is detected over the predetermined time window;
ii) an amplitude A of the monitoring parameter exceeds a predetermined a tolerance value tol, in the predetermined time window.

[0081] The diagnostic parameter is reset to zero in case the amplitude A of the monitoring parameter is detected to be lower than or equal to the tolerance value continually in the predetermined time window.

[0082] Moreover, the method comprises a step of increasing the value of the diagnostic parameter responsive to increments of the amplitude A and frequency of the oscillations of the monitoring parameter.

[0083] The method comprises a step of increasing the value of the diagnostic parameter by an increment based on a comparison between the amplitude A of the monitoring parameter in the predetermined time window and the tolerance tol value.

[0084] In particular, every time the mean value Xm is updated, a signal of the monitoring value is obtained by subtracting the actual detected value Xd from the mean value Xm in order to obtain a signal for the monitoring value as a function of time. Moreover, the number of zero-crossings of the monitoring parameter are detected in the pre-determined time window. In case there are no zero-crossings in the pre-determined time window, the value of the diagnostic parameter is equal to zero. In case zero-crossings are detected and the amplitude A of the signal is continually lower than the tolerance value over the pre-determined time window, the value of the diagnostic parameter is reset to zero.

[0085] In case zero-crossings are detected in the pre-determined time window and the amplitude A is greater than the value of the tolerance tol, the diagnostic parameter is increased. In an example the value of the diagnostic parameter is increased by adding a fixed amount thereto. In an example when the amplitude A is greater than the value of the tolerance tol and less than the amount of the mean value plus the value of the tolerance Xm+tol, the fixed value (amount) is equal to 1. When the amplitude A is greater than the amount of the mean value plus the value of the tolerance Xm+tol and less than the amount of the mean value plus twice the value of the tolerance Xm+2tol, the fixed value is equal to 2 and so on. In an example the method comprises a step of generating an alert signal responsive to the diagnostic parameter.

[0086] In an example the method comprises a step of generating a command signal to increase the speed of an impeller of the compressor 102, in case the diagnostic parameter exceeds a first threshold value. Moreover, in an example the method comprises a step of generating a command signal to shut the compressor down in case the diagnostic parameter exceeds a second threshold value.

[0087] The second threshold is greater than the first threshold value.

[0088] According to another aspect of the present description, the present invention provides a computer program. The computer program includes instructions to perform the steps of the method according to the present description when it is run on a processor.

Claims

1. A compressor surge detection system (1) for a re-

frigerating apparatus (100), wherein the refrigerating apparatus comprises:

- a compressor (101), for increasing the pressure of a refrigerating fluid, the compressor having an inlet (I) and an outlet (O), and an electrical motor driven by an inverter;
- an evaporator (102);
- a condenser (103),

the detection system (1) comprising:

- a sensing system, configured for detecting a monitoring parameter representative of a saturating evaporating temperature of the refrigerating fluid at the inlet (I) of the compressor;
- a processing unit, connected to the sensing system and programmed to process the monitoring parameter for deriving a diagnostic parameter, representative of an oscillatory behavior for the monitoring parameter with a periodicity shorter than 20 seconds, the processing unit being programmed for deriving an alert signal responsive to the diagnostic parameter.

2. The detection system (1) according to claim 1, wherein the processing unit is programmed for increasing the value of the diagnostic parameter responsive to increments of amplitude (A) and frequency of the oscillations of the monitoring parameter.

3. The detection system (1) according to claim 1 or 2 wherein the processing unit is programmed for deriving a mean value (X_m) for the monitoring parameter over a pre-established period of time and for setting the value of the monitoring parameter based on a difference between an actual detected (X_d) value for the monitoring parameter and the mean value (X_m-X_d)), wherein the processing unit is programmed for deriving the value of the diagnostic parameter in dependence of the number of zero-crossings of the monitoring parameter over a predetermined time window, wherein the pre-established period of time is shorter than 50 seconds, the processing unit being programmed for refreshing the mean value with periodicity set to the pre-established period of time.

4. The detection system (1) according to claim 3, wherein the processing unit is programmed to increase the value of the diagnostic parameter responsive to the following conditions being both verified:

i) a zero-crossing of the monitoring parameter is detected over a predetermined time window;
ii) an amplitude of the monitoring parameter exceeds a predetermined value defining a tolerance (tol) value, in the predetermined time window., wherein the processing unit is programmed to reset the diagnostic parameter to zero in case the amplitude (A) of the monitoring parameter is detected to be lower than or equal to the tolerance (tol) value continually in the predetermined time window.

5. The detection system (1) according to claim 4, wherein the processing unit is programmed to increase the value of the diagnostic parameter by an increment based on a comparison between the amplitude of the monitoring parameter in the predetermined time window and the tolerance value.

6. The detection system (1) according to claim 5, wherein a plurality of intervals is defined for the amplitude of the monitoring parameter A and a fixed amount is associated to each interval of the amplitude of the monitoring parameter, wherein the processing unit is programmed for increasing the value of the diagnostic parameter by adding the fixed amount, in response to the interval within which the amplitude of the monitoring parameter falls, thereto when a zero-crossing is detected, and the amplitude A is greater than the tolerance tol.

7. The detection system (1) according to any of the previous claims, wherein the compressor (102) includes an impeller and wherein the processing unit of the detection system is configured to generate a command signal to increase the speed of the impeller, in case the diagnostic parameter exceeds a first threshold value, and wherein the processing unit is configured to generate a command signal to shut the compressor (102) down in case the diagnostic parameter exceeds a second threshold value, the second threshold being greater than the first threshold value.

8. A refrigerating apparatus (100), comprising:

- a compressor (102), for increasing the pressure of a refrigerating fluid, the compressor having an inlet (I) and an outlet (O), and an electrical motor driven by an inverter;
- an evaporator (103);
- a condenser (104);
- a compressor surge detection system (1), to detect surge phenomena in the compressor, wherein the compressor surge detection system is according to any of the previous claims.

9. A method for detection of compressor surge for a refrigerating apparatus (100), the method comprising the following steps:

- detecting a monitoring value by a sensing system, the monitoring value being representative

of a saturating evaporating temperature of a refrigerating fluid at an inlet (I) of the compressor (102) of the refrigerating apparatus;
- sending the monitoring parameter from the sensing system to a processing unit;
- processing the monitoring parameter for deriving a diagnostic parameter, representative of an oscillatory behavior for the monitoring parameter with a periodicity shorter than 20 seconds;
- generating an alert signal responsive to the diagnostic parameter.

10. The method according to claim 9, further comprising a step of increasing the value of the diagnostic parameter responsive to increments of amplitude (A) and frequency of the oscillations of the monitoring parameter.

11. The method according to claim 9 or 10, further comprising the following steps:

- deriving a mean value (X_m) for the monitoring parameter over a pre-established period of time;
- setting the value of the monitoring parameter based on a difference between an actual detected value (X_d) for the monitoring parameter and the mean value,
- deriving the value of the diagnostic parameter in dependence of the number of zero-crossings of the monitoring parameter over a predetermined time window.
- refreshing the mean value with periodicity set to the pre-established period of time.

12. The method according to claim 11 comprising a step of increasing the value of the diagnostic parameter responsive to the following conditions being both verified:

i) a zero-crossing of the monitoring parameter is detected over a predetermined time window;
ii) an amplitude of the monitoring parameter exceeds a predetermined value defining a tolerance value (tol), in the predetermined time window,

wherein the diagnostic parameter is reset to zero in case the amplitude of the monitoring parameter is detected to be lower than or equal to the tolerance value continually in the predetermined time window.

13. The method according to claim 12 further comprising a step of increasing the value of the diagnostic parameter by an increment based on a comparison between the amplitude of the monitoring parameter in the predetermined time window and the tolerance value.

14. The method according to any of the previous claims from 12 to 13 comprising the following steps:

- generating a command signal to increase the speed of an impeller of the compressor, in case the diagnostic parameter exceeds a first threshold value;
- generating a command signal to shut the compressor down in case the diagnostic parameter exceeds a second threshold value,

the second threshold being greater than the first threshold value.

15. A computer program including instructions to perform the steps of claims 9 to 14 when run on a processor.

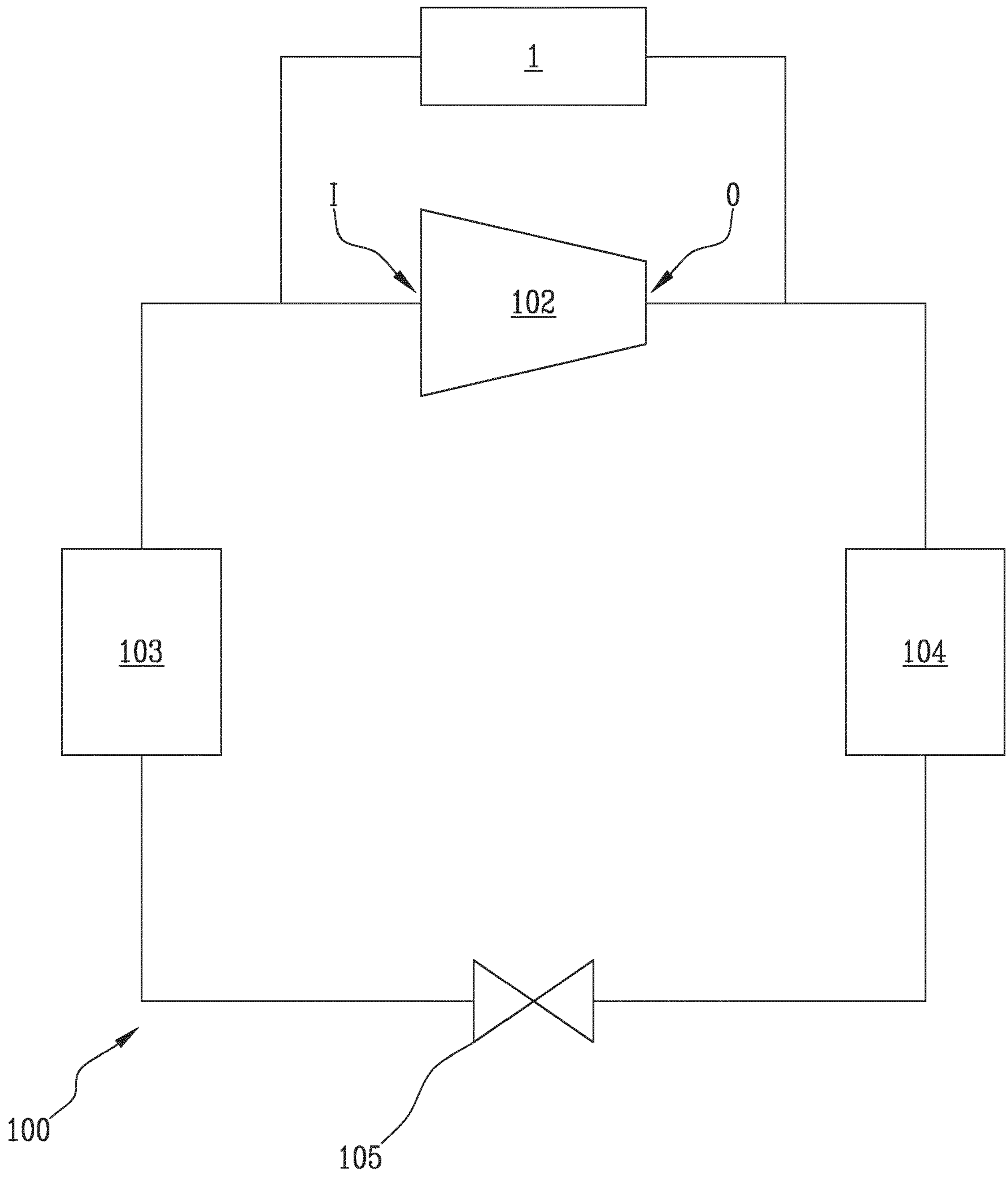

Fig.1

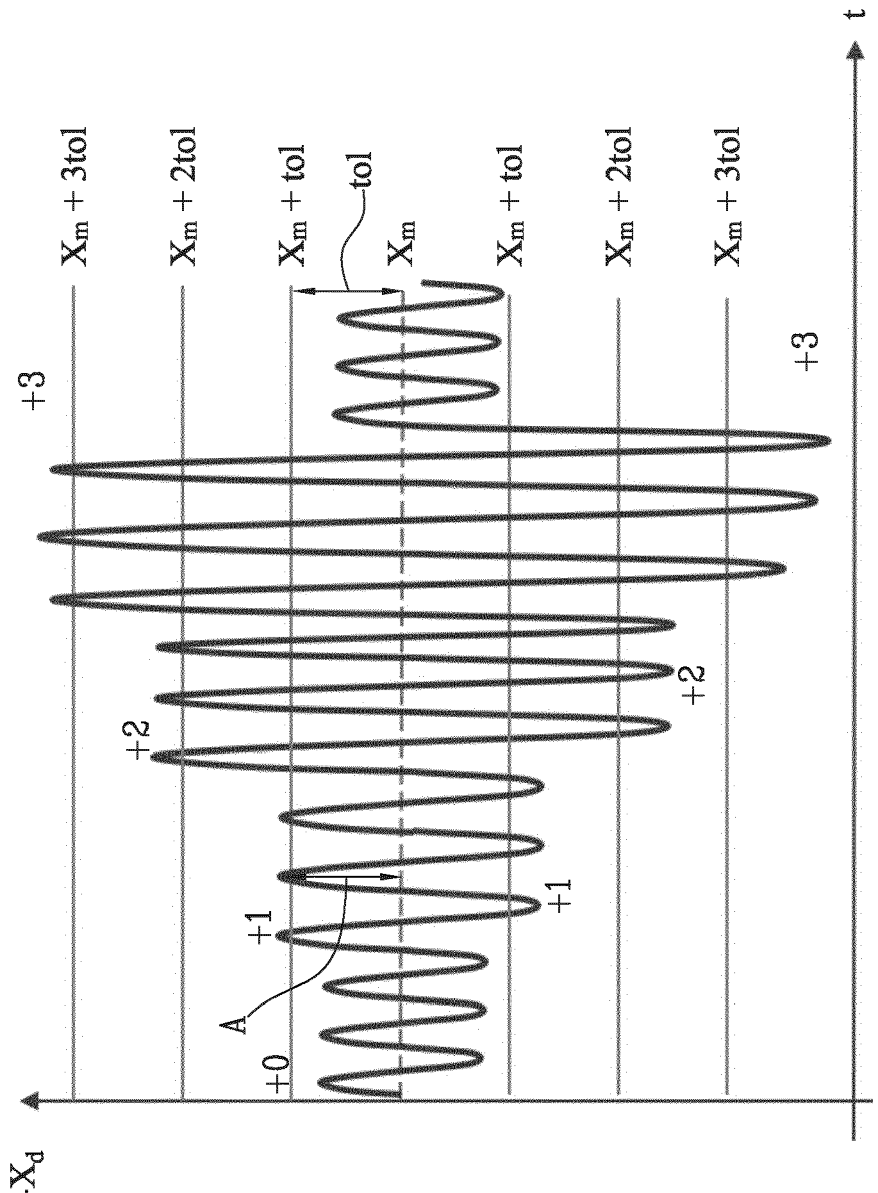
Xm-Xd
t
Xm + 3tol
Xm + 2tol
Xm + tol
tol
Xm
Xm + tol
Xm + 2tol
Xm + 3tol
+0
A
+1
+1
+2
+2
+3
+3

Fig.2

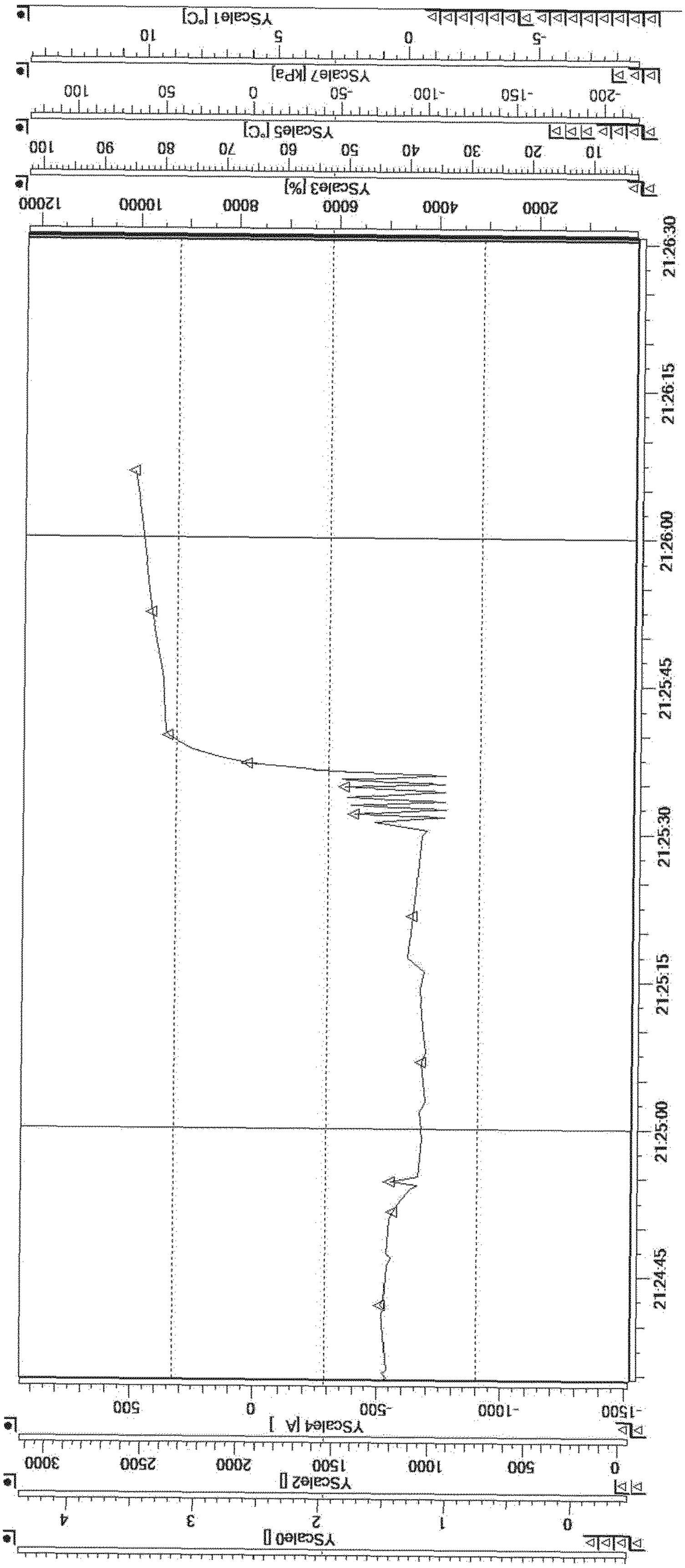

Fig.3

REFERENCES CITED IN THE DESCRIPTION

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