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(54) **Control device for a refrigerating machine**

Steuervorrichtung für ein Kühlgerät

Dispositif de commande d'une machine réfrigérante

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Description

[0001] The present invention concerns a control device for a refrigerating machine according to claim 1.

[0002] In particular, the present invention finds useful, but not exclusive, application in the regulation of the delivery temperature of a service fluid in output from a water chiller for centralized air-conditioning systems, to which the following description shall make explicit reference without, however, any loss of generality.

[0003] As is known, a centralized air-conditioning system for the control of the ambient temperature in a building comprises a plurality of fan coils, opportunely distributed inside the building and connected with each other via a hydraulic circuit, and a centralized refrigerating machine suited to cool a service fluid, in particular a coolant liquid substantially composed of water, and to convey this service fluid to the various fan coils via said hydraulic circuit.

[0004] This refrigerating machine, normally indicated by the term "chiller", comprises an internal circuit in which a working fluid consisting of a refrigerant circulates, an output circuit that connects to the hydraulic circuit of the air-conditioning system in correspondence to the unit's inlet and outlet to form, together with said hydraulic circuit, a so-called hydronic circuit, a heat exchanger through which the internal circuit and the output circuit pass for heat exchange between the working fluid and the service fluid, and one or more compressors for implementing a refrigeration cycle on the working fluid through compression of the working fluid itself.

[0005] Electronic control devices are also known of for controlling the switching on and off of the compressors on the basis of a direct comparison between a measurement of the temperature of the service fluid in output from the refrigerating machine, or rather the delivery temperature of the service fluid, and a pair of temperature thresholds such that the delivery temperature converges to a predetermined set point value. For instance, the U.S. patent application published with number US 2005/0235669 A1 discloses a control device according to the preamble of claim 1 for controlling the on/off switching of the compressor as a function of the comparison between the sensed temperature of an evaporating pipe and a pair of threshold temperatures.

[0006] Moreover, the refrigerating machine is typically equipped with a storage tank applied on the delivery branch of the hydronic circuit at a short distance from the heat exchanger to produce thermal inertia in the hydronic circuit that slows down the dynamics of the air-conditioning system in terms of speed of temperature variation in the service fluid so as to avoid phenomena that could induce instability in the system, such as undesired oscillations phenomena in the regulator valves of the fan coils for example. The delivery temperature, on the basis of which the switching on and off of the compressors is controlled, is typically taken downstream of the storage tank.

[0007] The storage tank is usually housed inside the metal casing that encloses the various mechanical components of the refrigerating machine, and so the size and cost of the refrigerating machine heavily depend on its presence. Therefore, for reasons of cost and overall dimensions, it is often attempted to reduce or even eliminate the storage tank, consequently making a refrigerating machine potentially capable of inducing the above-mentioned drawbacks.

[0008] The object of the present invention is to create a control device for a refrigerating machine and a refrigerating machine that allows the drawbacks caused by the absence of the storage tank to be overcome and that, at the same time, are simple and economic to manufacture.

[0009] According to the present invention, a control device for a refrigerating machine and a refrigerating machine in accordance with the attached claims are provided.

[0010] The present invention shall now be described with reference to the attached drawings, which illustrate a non-limitative example of embodiment, in which:

- Figure 1 shows a block diagram of an air-conditioning system comprising a refrigerating machine equipped with a control device in accordance with the present invention; and
- Figure 2 shows a table of values with which to configure certain parameters of the control device in Figure 1.

[0011] In Figure 1, reference numeral 1 generally designates a block diagram showing the principles of an air-conditioning system comprising a plurality of fan coils 2 opportunely distributed inside a building (not shown) for which it is wished to control the ambient temperature, and a refrigerating machine 3 suited to cool a service fluid 5, in particular a coolant liquid substantially composed of water, and make it circulate through a hydraulic circuit 4 that connects the fan coils 2 to the refrigerating machine 3 itself.

[0012] The refrigerating machine 3 comprises an internal circuit 6, in which a working fluid 7 consisting of a refrigerant circulates, and an output circuit 8, which connects to the hydraulic circuit 4 of the system 1 in correspondence to an inlet 9 and an outlet 10 of the refrigerating machine 3. A series of devices are arranged along the internal circuit 6 to implement a refrigeration cycle on the working fluid 7, and in particular, a first heat exchanger 11 through which the internal circuit 6 and the output circuit 8 pass and which functions as an evaporator to make the working fluid 7 evaporate at low pressure, absorbing heat from the service fluid 5; a compressor 12, preferably of the scroll type, to carry out adiabatic compression on the working fluid 7 in the vapour state; a second heat exchanger 13 functioning as a condenser, that is to make the working fluid 7 condense so as to release the previously absorbed heat to the outside, and an expansion valve 14 to cool the working fluid 7 and make it partially evaporate so that it is ready for another cycle.

[0013] The hydraulic circuit 4 of the system 1 and the output circuit 8 of the refrigerating machine 3 form a so-called hydronic circuit 15, comprising a delivery branch 16, along which the service fluid 5 circulates in a direction D from the heat exchanger 11 to the fan coils 2, and a return branch 17, along which the service fluid 5 returns to the heat exchanger 11. Circulation of the service fluid 5 in direction D is guaranteed by a pump 18 placed along the return branch 17.

[0014] In addition, the refrigerating machine 3 comprises a control device 19 to control the switching on and off of the compressor 12 based on the delivery temperature TLDV of the service fluid 5. More in detail, the control device 19 comprises a temperature sensor 20 placed along the delivery branch 16 at the outlet 10 of the refrigerating machine 3 to provide a first signal SDLV representing the delivery temperature TDLV and an electronic control unit 21 suited to switch the compressor 12 on and off on the basis of a comparison between a measurement of the delivery temperature TDLV, provided via the SDLV signal, and a pair of temperature thresholds such that the delivery temperature TDLV converges to a delivery temperature set point between the two temperature thresholds.

[0015] In accordance with the present invention, the control device 19 comprises a filter 22 connected in input with the sensor 20 to receive the signal SDLV and in output with the electronic control unit 21 to supply a corresponding signal SCTRL obtained by damping the dynamics of the SDLV signal according to a model that reconstructs the dynamic behaviour of a common storage tank. The SCTRL signal represents a delivery temperature with dampened dynamics, in the time domain, on the basis of which control of the compressor 12 is performed. In other words, a delivery temperature measurement is extracted from the SCTRL signal and compared with the above-mentioned temperature thresholds to switch the compressor 12 on or off.

[0016] More precisely, the filter 22 is modelled as a first order system with delay, of which the transfer function to the Laplace transform domain is given by:

$$F(s) = \frac{e^{-sT}}{1 + s \cdot P}, \qquad (1)$$

where T defines a delay between the input signal SDLV and the output signal SCTRL, and P represents a pole of the transfer function.

[0017] Therefore, by opportunely sizing the parameters T and P of function (1), it is possible to define a virtual storage tank that simulates the presence of a storage tank of the desired characteristics.

[0018] Indeed, two different phenomena occur, to differing extents, inside a storage tank: stratification, which consists in a division of the service fluid into layers according to the temperature, and mixing, which consists in the fact that part of the incoming service fluid is typically colder than that inside and absorbs part of the heat of the latter, converging to a temperature that can be defined as one of equilibrium. Consequently, the delay T represents the delay due to the stratification and parameter P is proportional to a mixing coefficient, which defines the volume percentage of the service fluid 5 in the tank that is affected by the mixing phenomena, at the density of the service fluid 5 in the hydronic circuit 15 expressed in kg/m^3 ad at a storage volume expressed in m^3 that it is wished to simulate, and is inversely proportional to the mass flow of the service fluid expressed in kg/s.

[0019] Figure 2 shows a table in which a series of values are listed that the parameters T and P must assume in order to simulate a corresponding series of tank volume values expressed in L/kW, i.e. expressed in litres with reference to the nominal power of the compressor 12. These values have been determined through experimental tests, applying a method known as the area method, which allows a system to be identified via its response to an input signal, such as a unitary step for example. The best compromise between damping the dynamics of the system 1 and the regulating speed of the delivery temperature TDLV is obtained by sizing the filter 22 for intermediate tank volumes, between 4 and 6 L/kW for example, and preferably for a tank volume value equal to 5 L/kW, to which there is a corresponding delay T substantially equal to 32.6 s and a parameter P substantially equal to 70.8 s.

[0020] It is worthwhile to note that the diagram of the principle of the refrigerating machine 3 shown in Figure 1 can also generically describe a machine suited to heat the service fluid 5 for the purpose of heating the environments in which the fan coils 2 are placed, for example a refrigerating machine 3 of the type operating as a heat pump. In this type of refrigerating machine 3, the compressor 12 is configured so as to perform the refrigeration cycle in the opposite sense to that previously described, such that the heat exchanger 11 functions as a condenser to transfer heat from the working fluid 7 to the service fluid 5 and the heat exchanger 13 functions as an evaporator. Furthermore, the sizing of the filter 22 is virtually independent of the fact of cooling or heating the service fluid 5. Thus, the control device 19 provided with the filter 22 is also applicable to a refrigerating machine suited to heat the service fluid 5.

[0021] The main advantage of the above-described control device 19 for a refrigerating machine 3 is to allow the elimination of the storage tank on the delivery branch 16 of the hydronic circuit 15, whilst still guaranteeing the necessary stability of the air-conditioning system 1 thanks to the presence of the filter 22, which defines a virtual storage tank.

Claims

1. Control device for a refrigerating machine (3) comprising a compressor (12), the control device (19) comprising temperature sensor means (20) to provide a first signal (SDLV) representing the delivery temperature (TDLV) of a service fluid (5) in output from the refrigerating machine (3), a control unit (21) suited to switch the compressor (12) on and off according to the first signal (SDLV), and signal damping means (22) to receive the first signal (SDLV) and to supply a corresponding dampened second signal (SCTRL) obtained by damping the dynamics of the first signal (SDLV) and suitable for being fed in input to the control unit (21) to control the said switching on and off of the compressor (12); **being characterized in that** said damping means comprising a first order filter (22) with delay to simulate an accumulation of said service fluid (5).

2. Device according to claim 1, in which said filter (22) has a Laplace transform domain transfer function given by:

$$F(s) = \frac{e^{-sT}}{1 + s \cdot P},$$

wherein T defines a delay between said first signal (SDLV) in input to the filter and said second signal (SCTRL) in output from the filter (22) and P is an accumulation parameter proportional to a storage volume of service fluid (5) that it is wished to simulate and to a mixing coefficient of the service fluid (5) in said storage volume.

3. Device according to claim 2, in which said filter (22) is sized for a value of said storage volume to simulate in the range from 4 to 6 L/kW.

4. Device according to claim 2 or 3, in which said delay (T) between said first signal (SDLV) and said second signal (SCTRL) is equal to 32.6 s and said accumulation parameter (P) is equal to 70.8 s.

5. Refrigerating machine (3) comprising a compressor (12) and a control device (19) for switching the compressor (12) on and off according to a measurement of the delivery temperature (TDLV) of a service fluid (5) in output from the refrigerating machine (3), and **characterized in that** the control device (19) is of the type asserted in one of the claims 1 to 4.

Patentansprüche

1. Steuervorrichtung für ein Kühlgerät (3) mit einem Kompressor (12), wobei die Steuereinrichtung (19) aufweist eine Temperatur-Sensoreinrichtung (20), um ein erstes Signal (SDLV) zu liefern, das die Abgabetemperatur (TDLV) eines Betriebsfluids (5) im Ausgang aus dem Kühlgerät (3) repräsentiert, eine Steuereinheit (21), die dazu geeignet ist, den Kompressor (12) gemäß dem ersten Signal (SDLV) ein- und auszuschalten, und eine Signal-Dämpfungseinrichtung (22), um das erste Signal (SDLV) zu empfangen und ein korrespondierendes gedämpftes zweites Signal (SCTRL) zu liefern, das durch ein Dämpfen der Dynamik des ersten Signals (SDLV) erhalten wird und dazu geeignet ist, in den Eingang zur Steuereinheit (21) geführt zu werden, um das Ein- und Ausschalten des Kompressors (12) zu steuern, **dadurch gekennzeichnet, dass** die Dämpfungseinrichtung ein Filter erster Ordnung (22) mit Verzögerung aufweist, um eine Akkumulation des Betriebsfluids (5) zu simulieren.

2. Vorrichtung nach Anspruch 1, in welcher das Filter (22) eine der Laplace-Transformation entsprechende Bereich-Übertragungsfunktion hat, die gegeben wird durch:

$$F(s) = \frac{e^{-sT}}{1 + s \cdot P'}$$

wobei T eine Verzögerung zwischen dem ersten Signal (SCLV) im Eingang zum Filter und dem zweiten Signal (SCTRL) im Ausgang vom Filter (22) definiert und P ein Akkumulationsparameter ist, der proportional ist zu einem

Speichervolumen des Betriebsfluids (5), das simuliert werden soll, und zu einem Mischkoeffizienten des Betriebsfluids (5) in dem Speichervolumen.

3. Vorrichtung nach Anspruch 2, in welcher das Filter (22) größenmäßig auf einen Wert des Speichervolumens angepasst ist, um in dem Bereich von 4 bis 6 L/kW zu simulieren.

4. Vorrichtung nach Anspruch 2 oder 3, in welcher die Verzögerung (T) zwischen dem ersten Signal (SDLV) und dem zweiten Signal (SCTRL) gleich 32,6 s ist und der Akkumulationsparameter (P) gleich 70,8 s ist.

5. Kühlgerät (3) mit einem Kompressor (12) und einer Steuereinrichtung (19) zum Ein- und Ausschalten des Kompressors (12) gemäß einer Messung der Abgabetemperatur (TDLV) eines Betriebsfluids (5) im Ausgang von dem Kühlgerät (3) und **dadurch gekennzeichnet, dass** die Steuereinrichtung (19) von der Bauart ist, die in einem der Ansprüche 1 bis 4 geltend gemacht wird.

Revendications

1. Dispositif de commande pour une machine de réfrigération (3) comprenant un compresseur (12), le dispositif de commande (19) comprenant des moyens de détection de température (20) pour fournir un premier signal (SDLV) représentant la température de distribution (TDLV) d'un fluide de service (5) en sortie de la machine de réfrigération (3), une unité de commande (21) appropriée pour mettre en marche et arrêter le compresseur (12) conformément au premier signal (SDLV), et des moyens d'amortissement de signal (22) pour recevoir le premier signal (SDLV) et pour délivrer un deuxième signal amorti (SCTRL) correspondant obtenu en amortissant la dynamique du premier signal (SDLV) et approprié pour être délivré en entrée à l'unité de commande (21) pour commander ladite mise en marche et ledit arrêt du compresseur (12) ; **caractérisé en ce que** lesdits moyens d'amortissement comprennent un filtre du premier ordre (22) avec un retard pour simuler une accumulation dudit fluide de service (5).

2. Dispositif selon la revendication 1, dans lequel ledit filtre (22) a une fonction de transfert de domaine de transformation de Laplace donnée par :

$$F(s) = \frac{e^{-sT}}{1 + s \cdot P},$$

où T définit un retard entre ledit premier signal (SDLV) en entrée du filtre et ledit deuxième signal (SCTRL) en sortie du filtre (22) et P est un paramètre d'accumulation proportionnel à un volume de stockage de fluide de service (5) qu'on souhaite simuler et à un coefficient de mélange du fluide de service (5) dans ledit volume de stockage.

3. Dispositif selon la revendication 2, dans lequel ledit filtre (22) est dimensionné pour une valeur dudit volume de stockage à simuler dans la plage de 4 à 6 L/kW.

4. Dispositif selon la revendication 2 ou 3, dans lequel ledit retard (T) entre ledit premier signal (SDLV) et ledit deuxième signal (SCTRL) est égal à 32,6 s et ledit paramètre d'accumulation (P) est égal à 70,8 s.

5. Machine de réfrigération (3) comprenant un compresseur (12) et un dispositif de commande (19) pour mettre en marche et arrêter le compresseur (12) conformément à une mesure de la température de distribution (TDLV) d'un fluide de service (5) en sortie de la machine de réfrigération (3), et **caractérisée en ce que** le dispositif de commande (19) est du type revendiqué dans l'une des revendications 1 à 4.

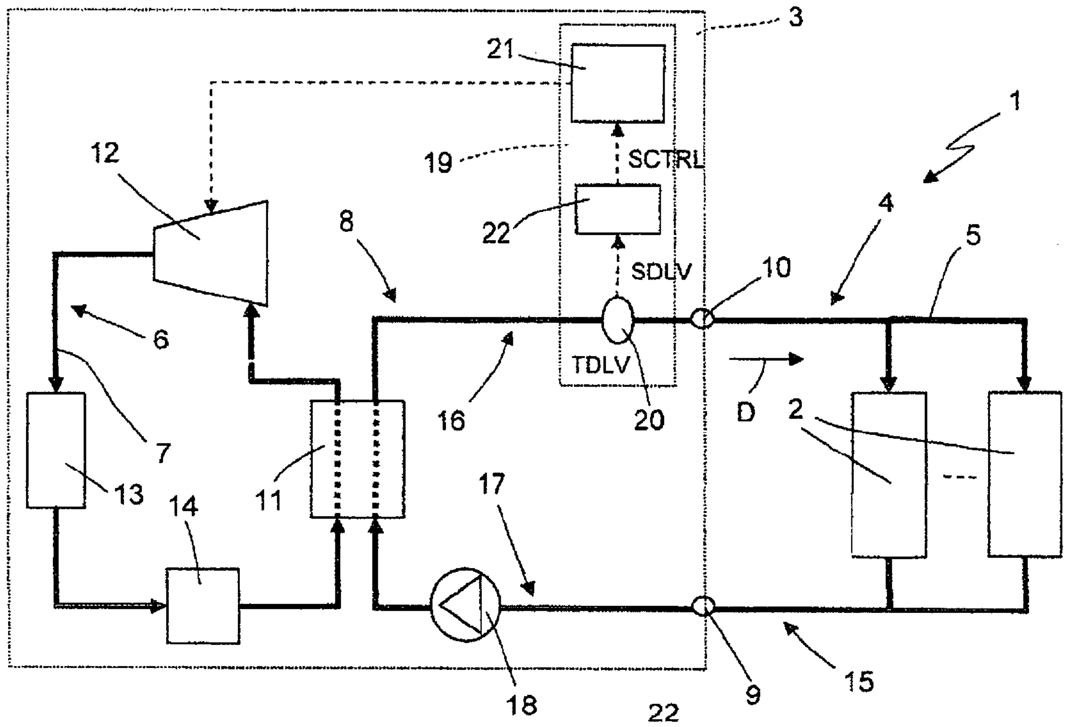

Fig. 1

L/kW	T	P
1	7.69	13.99
2	13.71	28.41
3	19.73	42.82
4	26.61	56.38
5	32.62	70.79
6	38.64	85.21
7	44.66	99.63
8	50.67	114.05
9	56.67	128.47
10	62.64	142.89

Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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