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(54) METHOD AND DEVICE FOR CONTROLLING A REFRIGERATION SYSTEM WITH A PLURALITY OF CHILLERS IN AN ARRANGEMENT OR NETWORK

(57) A method for controlling a refrigeration system comprising a plurality of chillers in an arrangement or network, at least some of which differ from each other in performance characteristics with respect to cooling capacity or power to be provided, electrical power consumed and cooling water temperature, comprising the steps of

a) detecting a requested target cooling capacity and a current cooling water temperature;

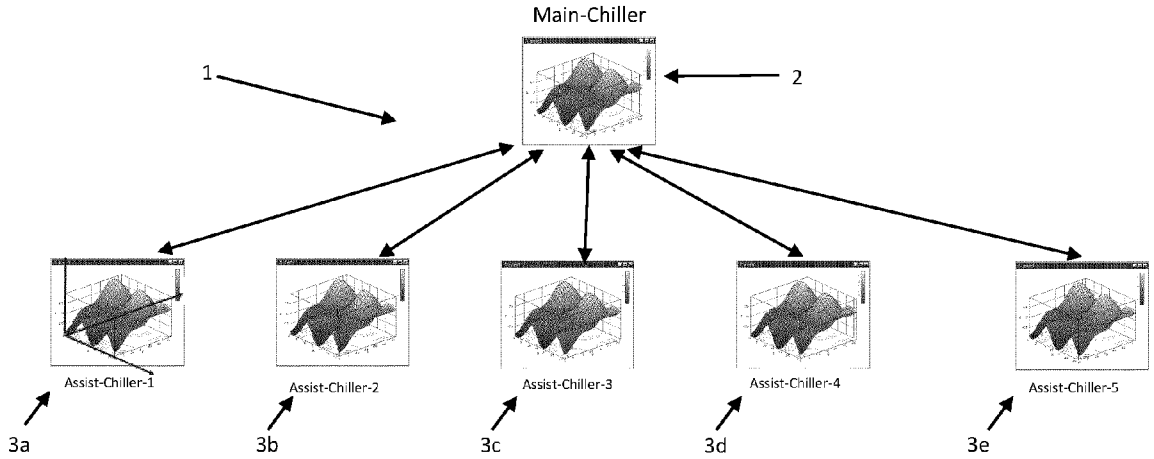
b) determining the available cooling capacity of the chillers in the network on the basis of the respective capacity characteristics and the detected current cooling water temperature;

c) determining the possible combinations of chillers that can provide the required target cooling capacity;

d) selecting, from the possible combinations of chillers and based on their respective performance characteristics, the combination that provides the highest overall efficiency; and

e) operating the chillers of the selected combination.

Fig. 1



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Description

[0001] The present invention relates to a method and a device for controlling a refrigeration system with a plurality of chillers in an arrangement or network, which differ from one another in their performance characteristics with regard to the cooling capacity which can be provided, the electrical power consumed and the cooling water temperature.

[0002] The terms chiller, refrigeration machine, and cooling unit are used synonymously in the following for a self contained mechanical refrigeration generator or compressor refrigeration generator whose refrigerant-carrying components such as evaporator, compressor, condenser and expansion device are pre-assembled at the factory and form a closed refrigerant or cooling circuit - in contrast to a direct evaporator. The working medium of the chiller can be any refrigerant known in the state of the art, but preferably water-based refrigerants for environmental and regulatory reasons.

[0003] The evaporator and condenser are typically designed as heat exchangers in the chiller and have the task of absorbing heat from the refrigerant or cooling circuit and later transferring it to another system via pipes/conduits, whereby the two processes take place with material separation. The heat dissipation from the condenser can be water-cooled via a recooling device in a separate coolant circuit or air-cooled. Optionally, the chillers can have a so-called free cooling function, in which the heat from the cold water is transferred directly to the outside air - possibly using the recooling device - if its temperature is low enough. The refrigerant or cooling circuit remains switched off and the electricity consumption, which is mainly caused by the compressor, is reduced, so that electricity consumption can be reduced and CO_2 savings can be achieved.

[0004] Every refrigeration machine of a certain type is known to have a typical performance diagram consisting of the cooling capacity that can be provided, the electrical power consumed and the cooling water temperature. Such an exemplary performance diagram is shown in Fig. 2, where the abscissa (X-axis) indicates the cooling or refrigeration capacity or power output (available/delivered), the ordinate (Y-axis) indicates the cooling water temperature, and the appicat (Z-axis) indicates the electrical power consumed. The axes can also be interchanged.

[0005] It should be noted that the performance diagram for a chiller without a by-pass valve is limited in terms of cooling capacity/power and electrical power in that such a chiller can only be controlled in a partial range of, for example, 30% to 100% and cannot be reduced to 0% output power. Accordingly, the cooling water temperature output by such a chiller is also limited.

[0006] The efficiency of the chiller (COP, EER or energy efficiency ratio) can be determined from the ratio of the cooling capacity/power to the electrical compressor power consumed. A high ratio stands for low power consumption combined with high cooling capacity. In principle, the efficiency ratio decreases as the difference between the cooling and ambient temperature increases. Therefore, each refrigeration machine can be operated at its maximum efficiency at a different output.

[0007] The cooling capacity required for the design of a refrigeration system for an object can be covered either with a single device or with a so-called cascade or network. The latter consists of plural chillers that are switched on and off as required. While this solution requires more space, in practice it often ensures greater efficiency because the operating times can be optimized by designing the refrigeration system in individual performance levels. The individual refrigeration machines or chillers operate for longer periods in the optimum performance range, they consume less and are also subject to less wear and tear, which occurs at high cycle rates (frequent start-up and shut-down).

[0008] However, the previous solutions for controlling such a cascade/network with several chillers in an arrangement are not satisfactory, in particular if refrigeration machines or chillers are combined in the arrangement, which differ from each other in terms of design or type and have different respective performance characteristics, i.e. differ in terms of the cooling capacity/power that can be provided, the electrical power consumed and the cooling water temperature.

[0009] The object of the invention is therefore to provide a method and a device for controlling a refrigeration system with a plurality of refrigerating machines or chillers in an arrangement or network, which differ from one another in terms of their performance characteristics with regard to the cooling capacity/power that can be provided, the electrical power consumed and the cooling water temperature, with which a higher overall efficiency and service life of the refrigeration system can be achieved.

[0010] As a solution, the invention proposes a method for controlling a refrigeration system with a plurality of refrigerating machines/chillers according to claim 1 and a device for controlling a refrigeration system with a plurality of refrigerating machines/chillers according to claim 11. Preferred embodiments are defined in the respective dependent claims.

[0011] Accordingly, the invention relates in particular to a method for controlling a refrigeration system with a plurality of refrigerating machines/chillers in an arrangement or network, at least some of which differ from one another in terms of their performance characteristics with regard to the cooling capacity/power that can be provided, the electrical power consumed and the cooling water temperature, comprising the steps of

a) detecting a requested target cooling capacity and a current cooling water temperature;

b) determining the available cooling capacity of the chillers in the arrangement/network on the basis of

the respective performance characteristics and the determined current cooling water temperature;

c) determining the possible combinations of chillers that can provide the required target cooling capacity;

d) selecting, from the possible combinations of chillers and based on their respective performance characteristics, the combination that provides the highest overall efficiency; and

e) operating the chillers of the selected combination.

[0012] By taking into account the respective performance characteristics of the available chillers and selecting or assembling a combination of several chillers within the arrangement/network with a view to maximizing the overall efficiency, the power consumption of the overall system can be reduced - with a specified target cooling capacity requested by a consumer - and, as a result, CO_2 emissions and operating costs can be flexibly optimized. The provision of several chillers also provides a certain redundancy, so that even if individual chillers fail, e.g. due to maintenance or repair, a suitable combination of chillers can always be selected flexibly and automatically to meet a current performance requirement or demand.

[0013] Preferably, the method comprises repeating steps c) to e) if the requested target cooling capacity or the detected current cooling water temperature changes. This allows the optimum combination of chillers within the system to be determined even if the required output or demand and/or relevant ambient conditions change.

[0014] Preferably, the operation of the chillers of the selected combination is controlled by adjusting the output of the respective chiller, preferably by adjusting the hot water mass flow that is supplied to the respective chiller. The hot water mass flow can preferably be controlled by activating the feed pump in the cold or hot water circuit of the respective chiller, whereby the output of the feed pump can preferably be modulated continuously or in stages, for example by controlling the rotational speed. The respective chiller regulates itself depending on the hot water flow supplied.

[0015] Preferably, during the step of selecting the combination of chillers to be operated in order to fulfill a performance requirement or demand, if several chillers with the same performance characteristics are present in the network, the combination with the chiller with the same performance characteristics is selected which has the lowest number of operating hours. This further boundary condition can achieve a uniform increase in the operating hours of the individual comparable chillers, which simplifies maintenance and monitoring of the overall system and reduces the risk of failure of individual chillers due to excessive wear.

[0016] Preferably, in the step of selecting the combination of chillers to be operated in order to meet a performance requirement or demand, the combination with the lowest number of chillers to be operated is selected. Reduced wear can also be achieved by this further boundary condition, which simplifies maintenance and monitoring of the overall system and reduces the risk of failure of individual chillers due to excessive wear of individual chillers. It should be noted that more powerful chillers are generally also designed for a longer service life and higher efficiency.

[0017] Preferably, the combination that requires the lowest number of machine starts is selected in the step of selecting the combination. Reduced wear can also be achieved through this additional boundary condition, which simplifies maintenance and monitoring of the overall system and reduces the risk of failure of individual chillers due to excessive wear. It should be noted that frequent starts lead to higher wear due to mechanical friction and alternating thermal loads.

[0018] Preferably, the process, in particular steps a) to e), is carried out centrally by a main chiller in the system, which controls the other chillers in the system as auxiliary or assist chillers. The main chiller can typically and preferably be the most powerful machine in the system, which also provides the largest proportion of the system's capacity due to its design and will therefore have the longest operating times, so that this machine will be used in the vast majority of combinations.

[0019] Preferably, the main chiller in the combination also controls peripheral devices of the refrigeration system, preferably a jointly used re-cooling device 4 (see Fig. 3) and/or a free-cooling device to which all the chillers of the arrangement are connected by cooling medium lines. The efficiency of the overall system can be optimized by centrally controlling the peripheral devices as well, for example by centrally switching off components such as pumps, valves, etc. that are not required for a particular operation and the provision of a current power requirement or demand, thereby reducing the power consumption of the overall system.

[0020] Preferably, the main chiller in the arrangement network also monitors malfunction in the chillers in the arrangement/network. The central monitoring of all chillers enables simplified maintenance and malfunctions that lead to the failure of a chiller can be taken into account directly when determining the chillers available for a current target cooling capacity.

[0021] The invention then also relates in particular to a device for controlling a refrigeration system with a plurality of refrigeration machines in an arrangement/network, which differ from one another in terms of their performance characteristics with regard to the cooling capacity or power that can be provided, the electrical power consumed and the cooling water temperature, the device being designed to carry out the method according to the invention. The device can be implemented as a component of a central control system and can be provided either directly at a control station of the system, for example at a main chiller, or via remote access at a remote position.

[0022] In the following, the invention is explained with reference to an embodiment shown in the figures, where:

Fig. 1 is a schematic diagram of an arrangement of several chillers in an arrangement or network, in which a main chiller centrally controls a number of auxiliary or assist chillers;

Fig. 2 shows an exemplary 3-dimensional performance diagram of a chiller, which graphically illustrates the function or relationship of the relevant parameters for the primary selection of the chillers in the network: cooling or refrigeration capacity or power delivered (available) on the abscissa (X-axis), cooling water temperature on the ordinate (Y-axis), and electrical power consumed on the appicat (Z-axis); and

Fig. 3 is a further diagram showing the hydraulic connections and the data connections of several chillers (here 3) in an arrangement or network in a refrigeration system, of which one machine with the largest capacity (e.g. 120 kW) acts as the main chiller and the others with lower capacity (e.g. 45 kW) are centrally controlled as auxiliary or assist chillers.

[0023] The method according to the invention for controlling a refrigeration system 1 with several chillers 2, 3a to 3e in an arrangement or network, at least some of which differ from one another in terms of their performance characteristics with regard to the cooling capacity or power that can be provided, the electrical power consumed and the cooling water temperature, is described below using the network shown in Fig. 1 and Fig. 3 as an example, in which several chillers are provided, of which one machine, preferably the one with the highest capacity (e.g. 120 kW), acts as the main chiller and the others, preferably with a lower capacity (e.g. 45 kW), are centrally controlled as auxiliary or assist chillers.

[0024] First, a consumer requests a target or demand cooling capacity from the system and this request is detected by the main chiller. The main chiller then determines which possible combinations of chillers in the network, including itself, can provide the requested target cooling capacity. The main chiller then determines the cooling water temperature of the respective chiller. With this information, the respective 3-dimensional performance diagram can be reduced to a 2-dimensional performance diagram with absorbed electrical power and delivered cooling power on the basis of the respective performance characteristics (see Fig. 2, for example) of the chillers. By adding the values from the 2-dimensional performance diagram and a low point minimum determination, the combination that provides the highest overall efficiency can be determined from the possible combinations of chillers and selected for operation to provide the target cooling capacity. This means that the demand directed to the main chiller (target cooling capacity) is distributed by the main chiller to itself and the individual further chillers in the system in an optimum manner in terms of overall efficiency.

[0025] The above procedure for selecting an optimum combination of available chillers is repeated if the requested target cooling capacity or the detected current cooling water temperature changes.

[0026] After selecting the optimum combination of chillers for a requested target cooling capacity or cooling water temperature, the main chiller controls the associated auxiliary or assist chillers and itself (and switches off any machines that are not required or can be switched to standby mode with minimum or 0% capacity.

[0027] For this purpose, the main chiller adjusts the output of the respective chiller, preferably by adjusting the hot water mass flow rate supplied to the respective chiller, whereby the hot water mass flow rate supplied to the respective chiller can be adjusted by controlling a feed pump 5 in a respective hot water circuit 6 (see Fig. 3).

[0028] Communication between the main chiller and the auxiliary or assist chillers, the consumer and any peripheral devices in the system preferably takes place via the Modbus communication protocol (MODBUS TCP).

[0029] In addition to the basic determination of the possible combinations of chillers in the network that can practically provide a requested target cooling capacity at a given cooling water temperature, the main chiller can also take other boundary conditions into account when selecting the chillers that are ultimately controlled for operation. These boundary conditions can include the selection of the chiller with the lowest number of operating hours in a combination of several chillers with the same performance characteristics, i.e. chillers of the same design, are present in the system. Furthermore, these boundary conditions can prioritize a selection of the combination that has the lowest number of chillers to be operated. Finally, these boundary conditions can prioritize a selection of the combination that requires the lowest number of machine starts. Which of these boundary conditions is then given priority must be determined in advance.

[0030] The central control of the system by the main chiller also offers the possibility of detecting faults or malfunctions in all chillers in the system. The central monitoring of all chillers enables simplified maintenance and faults or malfunctions that lead to the failure of a chiller can be taken into account immediately when determining the chillers available for a current target cooling capacity. For example, in the event of a fault or failure, a replacement chiller of suitable capacity can be switched on without any relevant time delay or a new selection can be determined if this is not possible.

[0031] Furthermore, the operating capacity utilization of all machines in the network can be monitored and the activation and deactivation or selection of the chillers can be carried out with a view to achieving uniform operating hour utilization of at least comparable machines.

[0032] Finally, the central monitoring of all chillers in the network enables a central visualization of the most important machine data of the arrangement or network.

[0033] It should be noted that the chiller acting as the central control unit (the main chiller) does not necessarily have to be the one with the highest capacity.

[0034] It should also be noted that the steps for selecting the optimum combination of chillers do not necessarily have to be carried out in the specified order.

Claims

1. A method for controlling a refrigeration system with a plurality of refrigerating machines in a network, at least some of which differ from one another in the performance characteristics with regard to the cooling capacity or power which can be provided, the electrical power consumed and the cooling water temperature, comprising the steps of

   a) detecting a requested target cooling capacity and a current cooling water temperature;
   b) determining the available cooling capacity of the chillers in the network on the basis of the respective capacity characteristics and the detected current cooling water temperature;
   c) determining the possible combinations of chillers that can provide the required target cooling capacity;
   d) selecting, from the possible combinations of chillers and based on their respective performance characteristics, the combination that provides the highest overall efficiency; and
   e) operating the chillers of the selected combination.

2. The method according to claim 1, comprising repeating steps c) to e) in case the requested target cooling capacity or the detected actual cooling water temperature changes.

3. The method according to claim 1 or 2, wherein the operation of the chillers of the selected combination is controlled by adjusting the capacity of the respective chiller, preferably by adjusting the hot water mass flow supplied to the respective chiller.

4. The method according to claim 3, wherein the adjustment of the hot water mass flow supplied to the respective chiller is carried out by controlling a feed pump in a respective hot water circuit.

5. The method according to any one of claims 1 to 4, wherein in the step of selecting the combination, if several chillers with the same output characteristic are present in the combination, that combination is selected with the chiller with the same output characteristic which has the lowest number of operating hours.

6. The method according to any one of claims 1 to 5, wherein in the step of selecting the combination, that combination is selected which has the lowest number of chillers to be operated.

7. The method according to any one of claims 1 to 6, wherein in the step of selecting the combination, that combination is selected which requires the smallest number of machine starts.

8. The method according to any one of claims 1 to 7, wherein the method, in particular steps a) to e), is carried out centrally by a main chiller in the network, which controls the remaining chillers in the network as auxiliary or assist chillers and which preferably has the highest capacity of the chillers present in the network.

9. The method according to claim 8, wherein the main chiller in the network also controls peripheral devices of the refrigeration system, preferably a re-cooling device and/or a free-cooling device.

10. The method according to claim 8 or 9, wherein the main chiller in the network also monitors malfunctions of the chillers of the network.

11. An apparatus for controlling a refrigeration system comprising a plurality of chillers in an arrangement or network which differ from each other in the performance characteristics with respect to cooling capacity or power to be provided, electrical power consumed and cooling water temperature, wherein the apparatus is designed to carry out the method according to any one of claims 1 to 10.

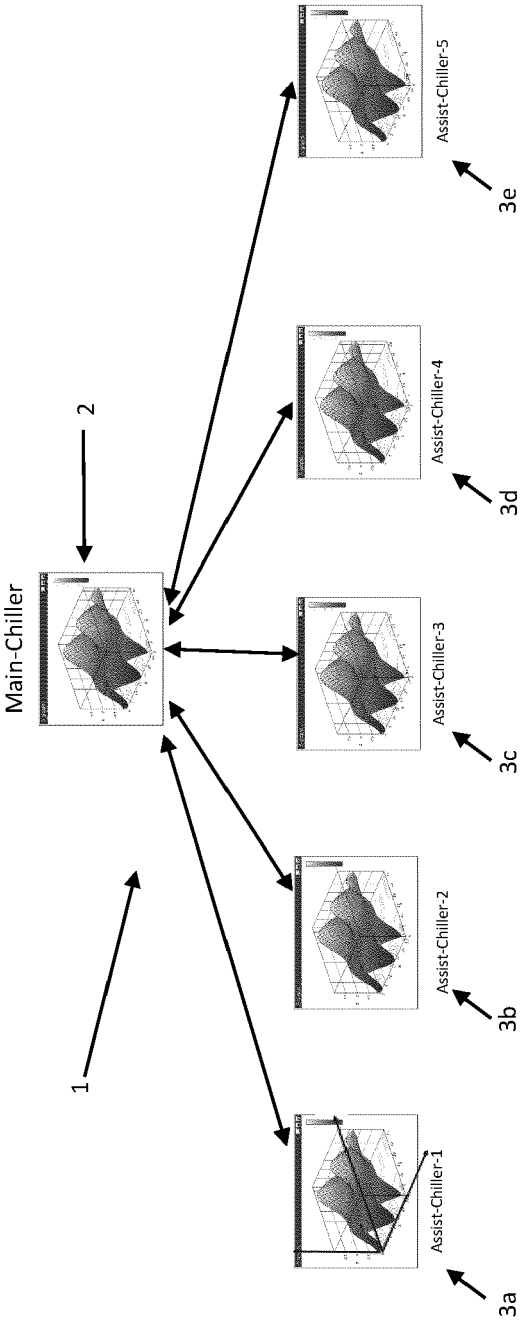
Main-Chiller
2
1
Assist-Chiller-1
3a
Assist-Chiller-2
3b
Assist-Chiller-3
3c
Assist-Chiller-4
3d
Assist-Chiller-5
3e

Fig. 1

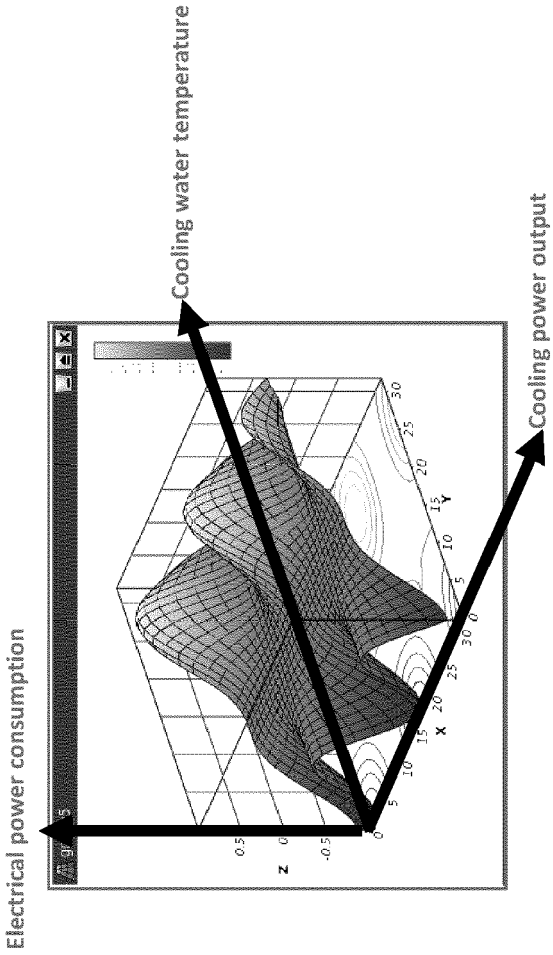
Cooling water temperature
Cooling power output
Electrical power consumption
X
Y
Z

Fig. 2

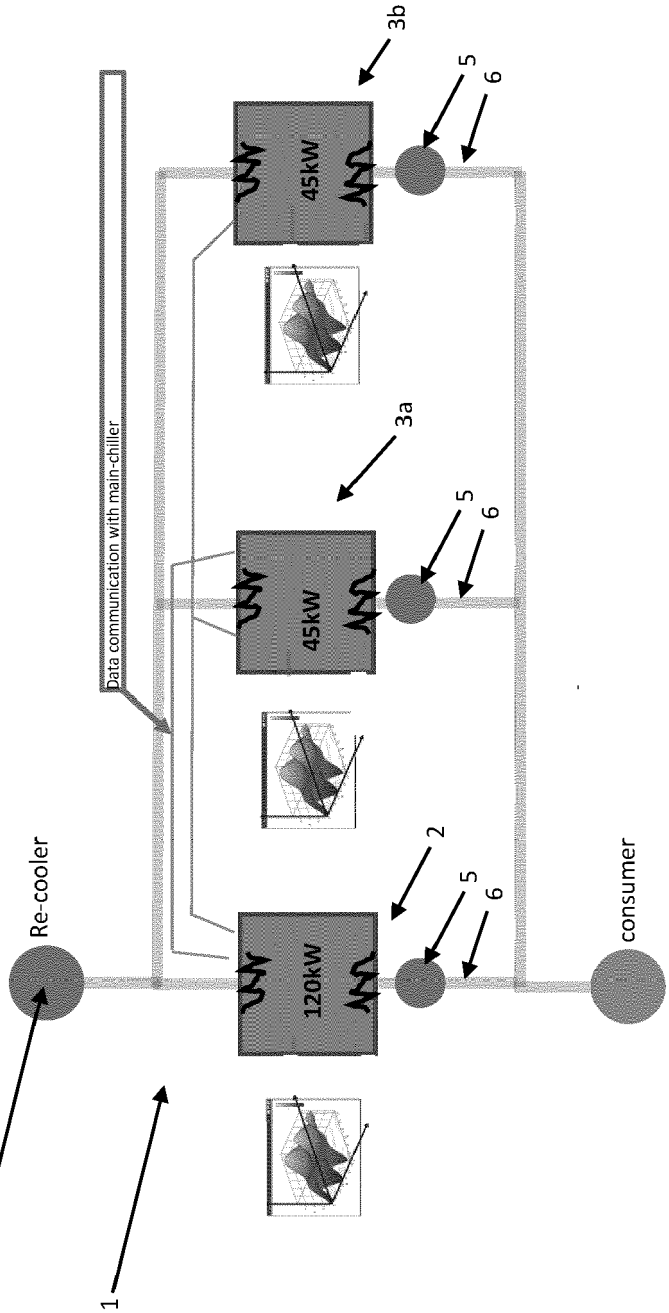
3b
5
6
45kW
3a
5
6
45kW
Data communication with main-chiller
2
5
6
120kW
Re-cooler
consumer
4
1

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 23 22 0368

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 463 574 A (SPETHMANN DONALD H [US] ET AL) 7 August 1984 (1984-08-07) * column 3, line 15 - column 8, line 59; figures 1-8 *	1-11	INV. F25B49/02
X	US 2022/373210 A1 (TILLACK LAWERENCE E [US]) 24 November 2022 (2022-11-24) * paragraphs [0046] - [0081]; figures 1-7 *	1-11	

TECHNICAL FIELDS SEARCHED (IPC)

F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 April 2024	Weisser, Meinrad

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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24-04-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4463574 A	07-08-1984	CA 1192288 A	20-08-1985
		US 4463574 A	07-08-1984
US 2022373210 A1	24-11-2022	NONE	

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