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Controlled hydronic distribution system

Abstract

A hydronic distribution system obtains, in real time, valve operating information from one or more valves arranged in a network, executes a speed determination algorithm which processes the valve operating information to determine a desired speed for one or more pumps to maintain a desired amount of process fluid flow of a process fluid to plural coils, and sets a speed of the one or more pumps, based on the desired speed for the one or more pumps that is determined.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. application Ser. No. 16/819,580, filed Mar. 16, 2020, which is a continuation application of U.S. application Ser. No. 15/729,546, filed Oct. 10, 2017 (now U.S. Pat. No. 10,612,794), which is a continuation application of U.S. application Ser. No. 14/930,348 filed on Nov. 2, 2015 (now U.S. Pat. No. 9,810,438), which is a divisional application of U.S. application Ser. No. 13/219,481, filed on Aug. 26, 2011 (now abandoned), the contents of each of which are hereby incorporated by reference in their entireties as if fully set forth herein.

FIELD OF THE INVENTION
(1) The present invention generally relates to systems and methods for networking a series of valves operating in a hydronic distribution system and also controlling the valves with a microprocessor that communicates flow and temperature information to variable speed pumps.
BACKGROUND OF THE INVENTION
(2) Conventional hydronic distribution systems utilized in many buildings include a variable speed drive that relies on differential pressure measurements within the system to control the speed for one or more variable speed pumps that supply fluid to a chiller or boiler. For example, FIG. **1** shows a prior-art, closed-loop, hydronic, distribution system **10** having a chiller/boiler **12** in fluid communication with two variable speed pumps **14**. In turn, the pumps **14** are electronically controlled by a variable speed drive **16** that receives differential pressure information **18** from one or more differential pressure sensors **20**. The sensed pressure is the pressure difference between a first point **22** upstream of at least one of the coils **24** and a second point **26** downstream of at least one of the self-regulating valves **28**. If the hydronic distribution system **10** operates as a heating system, then hot fluid from the boiler **12** proceeds to cooling coils **24**, and conversely if the hydronic distribution system **10** operates as a cooling system, then cool fluid from the chiller **12** proceeds to warming coils **24**. A flow controlled bypass **29** valve may also be included to divert fluid from the discharge of the pump(s) to the return line of the chiller or boiler in order to maintain minimum flow through the boiler or chiller at all times.
(3) The pressure sensor **20** typically monitors the differential pressure across the supply and return header **30**, but other points of differential pressure measurement are sometimes used, and the pressure information is utilized by the variable speed drive **16** to control the speed of the pumps **14** to maintain the differential pressure within a desired range of a predetermined differential pressure

set-point for across the header **30**. The pressure set-point is established so that the system **10** will satisfy the required amount of process fluid flow at all loads under all operating conditions.

(4) Control of the pumps to maintain the pressure set-point may be based on a proportional and integral (PI) or proportional, integral and derivative (PID) control loop theory. In typical operation, the monitored differential pressure decreases as the valves **28** open showing more demand for process fluid in the system **10**. As a result, the pumps **14** speed up to maintain the set-point pressure and provide the required fluid. If the valves **28** begin to close, then the differential pressure increases, which in turn causes the pumps **14** to slow down in order to maintain the set-point pressure. The illustrated system **10** and associated distribution method using differential pressure is considered the standard method of fluid control through a hydronic distribution system.

BRIEF SUMMARY OF THE INVENTION

(5) A hydronic distribution system includes self-regulating valves and a microprocessor that receives temperature information from the valves, and in turn provides commands to a variable speed drive for controlling the speed of one or more pumps within the system. The microprocessor may also utilize information as to the position of the valves (e.g., open, closed, or somewhere in between) to generate the commands to the variable speed drive. In one embodiment, the microprocessor compares an actual change in position of the valve to determine whether the pump speed should be changed.

(6) In one aspect of the present invention, a hydronic distribution system includes a chiller, a variable speed drive; a variable speed pump in electronic communication with the variable speed drive and in fluid communication with the chiller; a plurality of coils in fluid communication with the chiller; a plurality of self-regulating valves arranged to control an amount of fluid flow from the variable speed pump through each coil; a plurality of sensors respectively cooperating with the plurality of self-regulating valves, the sensors configured to determine a temperature of the fluid leaving the respective valve; and a microprocessor configured to receive the temperatures from the sensors, process the temperatures within an algorithm, to drive the position of the valves to best match the fluid requirement of the coil, The processor will then calculate the required speed of the pump from the position of the valve and provide speed control to the variable speed drive to establish a desired speed of the pump.

(7) In another aspect of the invention, a method for controlling a hydronic distribution system includes the steps of (1) networking a plurality of self-regulating valves to control an amount of fluid flow from at least one variable speed pump to a plurality of coils, wherein the coils are in fluid communication with a chiller that receives fluid from the pump as determined by a variable speed drive; (2) detecting a valve position for each of the valves; (3) transmitting the valve positions to a microprocessor; (4) determining a desired speed of the variable speed pump; and (5) determining an amount of process fluid flow required by the hydronic distribution system.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Preferred and alternative embodiments of the present invention are described in detail below with reference to the following drawings:

(2) FIG. **1** is a prior-art, schematic diagram of a hydronic distribution system having control valves and a differential pressure sensor for monitoring pressure across a portion of the system;

(3) FIG. **2** is a schematic diagram of a hydronic distribution system having self-regulating valves and a microprocessor for receiving temperature information from the valves according to an embodiment of the present invention;

(4) FIG. **3** is a schematic diagram of a hydronic distribution system having self-regulating valves, a microprocessor for receiving temperature information from the valves, and a reference set-point

temperature for the system according to an embodiment of the present invention; and

(5) FIGS. **4**A and **4**B are flow diagrams of an algorithm for a hydronic distribution system according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

(6) In the following description, certain specific details are set forth in order to provide a thorough understanding of various embodiments of the invention. However, one skilled in the art will understand that the invention may be practiced without these details. In other instances, well-known structures associated with hydronic distribution systems, the operating components used therein, computing and/or processing systems, various system operational parameters, and methods of operating a hydronic distribution system have not necessarily been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments of the invention.

(7) The present method for controlling pump speed in a conventional hydronic distribution system requires differential pressure control in which a pressure sensor typically monitors the differential pressure across the supply and return header or across one of the valves and load at the end of the system. The speed of the pumps are controlled to maintain a particular set-point pressure, which is generally established or predetermined so the system will continually have the necessary amount of process fluid flow at all anticipated loads and under all anticipated operating conditions.

(8) However, one problem in conventional hydronic distribution systems and the conventional methods for controlling pump speed is the set-point pressure is established at a high level to handle the worst case conditions. This high set-point pressure causes excessive pumping energy under more typical or normal operating conditions and also contributes to loss of process fluid energy in cooling systems.

(9) To reduce energy loss at the valves, one embodiment of the present invention provides self-regulating valves networked together and operable to share valve temperature and valve position information with a microprocessor or other type of controller. The microprocessor runs one or more algorithms that process the temperatures and positions of the valves and then compute a desired speed (e.g., lowest speed) for one or more variable speed pumps within the system. Controlling the pumps to operate at their lowest speed and still maintain the correct amount of process fluid flow needed by the system reduces the overall energy use of the hydronic distribution system, saves on the operational lives of the pumps, and increases system efficiency.

(10) FIG. **2** shows a hydronic distribution system **100** having a chiller/boiler **102** in fluid communication with one or more pumps **104**. The system **100** in the illustrated embodiment includes two pumps, but a single pump may be used or more than two pumps depending on the demands of the system **100**. A flow controlled bypass valve **105**, which may take the form of a three-way valve, may also be included to divert fluid from the discharge of the pump(s) to the return line of the chiller or boiler in order to maintain minimum flow through the boiler or chiller at all times. The speed of each pump **104**, and in turn the amount of fluid pumped through the system **100**, is governed by variable speed drives **106**, **107** which in turn are controlled by a computing device **108**, which may preferably take the form of a microprocessor. The microprocessor **108** receives information from a differential pressure sensor **110** and a plurality of self-regulating valves **112** disposed within the system **100**. The valves **112** are in fluid communication with a plurality of heating or cooling coils **114**, respectively. The sensor **110** and the valves **112** are networked with the microprocessor **108** to communicate pressure information **116** and valve operating information **118** to and from the microprocessor **108**.

(11) In the illustrated embodiment, the self-regulating valves **112** provide the valve operating information **118**, which may include, but is not limited to, fluid temperatures of the fluid leaving the each valve **112**, respectively, which may be compared to a set-point temperature (FIG. **3**) to maintain the fluid temperatures within a predetermined temperature range. In addition, the valve operating information **118** may also include valve position information to indicate whether the valve is open, closed, or at some position therebetween. The valve operating information **118** is

received by the microprocessor **108** and entered into one or more algorithms programmed into the microprocessor **108**. Based on the algorithm or algorithms, the microprocessor **108** transmits one or more signals to the variable speed drive **106** to establish a desired speed for one or both pumps **104** that permits the system **100** to make real time adjustments to various loads while maintaining the correct amount of fluid flow to the system components and throughout the system **100**.

(12) The microprocessor **108** operates the variable speed drive **106** to control the speed of the pumps as to maintain a highest possible average valve position while ensuring that no valve is fully open with the load unsatisfied, which is determined by the return fluid temperature information **118**. By way of example, if any valve position increases (becomes more open) then the algorithm(s) in the microprocessor **108** determines the percentage position of the valve increasing, and there is a particular weighted value attributed to each valve within the algorithm, so as a valve position increases, the weighted result also increases. These weighted results are summed together to determine pump speed in response to an increased demand for process fluid within the system **100**. As such, the microprocessor **108** will produce a signal **120** for the variable speed drive **106**, which in turn provides a speed signal **122** to increase the speed of one or both pumps **104**.

(13) Alternatively, if any valve position decreases (becomes more closed) then the algorithm in the microprocessor **108** may determine that there is a decreased demand for process fluid in the system **100**. In this situation, the microprocessor will produce the signal **120** for the variable speed drive **106**, which in turn provides the speed signal **122** to decrease the speed of one or both pumps **104** to meet the demand and provide the required process fluid. This active control of the pumps **104** by continually or at least periodically processing the valve operating information **118** received from the networked valves **112** may provide a more optimum and more efficient method of fluid control through the hydronic distribution system **100**. The decreased demand may be determined by the percentage position of the valve closing, and there is a particular weighted value attributed to each valve within the algorithm, so as a valve position decreases the weighted result also decreases. These weighted results from each valve are summed together to a lower determine pump speed.

(14) FIG. **3** shows another hydronic distribution system **200** that is configured and operates similar to the hydronic distribution system **100** described above. As such, the reference numerals of the similar components are merely incremented by "one hundred" and they are not described in detail herein. In the illustrated embodiment, the networked, self-regulating valves **212** provide the valve operating information **218** to the microprocessor **208** for controlling the variable speed drive **206**, which in turn governs the speed of the pumps **204**. A flow controlled bypass valve **205**, which may take the form of a three-way valve, may also be included to divert fluid from the discharge of the pump(s) to the return line of the chiller or boiler in order to maintain minimum flow through the boiler or chiller at all times. The speed of each pump **204**, and in turn the amount of fluid pumped through the system **200**, is governed by variable speed drives **206**, **207** which in turn are controlled by a computing device **208**, which may preferably take the form of a microprocessor.

(15) The system **200** includes a second algorithm, module or program accessible by the microprocessor **208** that determines a desired set-point temperature for the process fluid while the aforementioned algorithm determines and controls the pump speed based on the networked valves **212** and corresponding valve information **218**. More specifically, the microprocessor **208** in the illustrated embodiment utilizes one or more algorithms to determine an optimum process fluid temperature from a result of a speed set-point.

(16) In operation, the valves **212** forward or the microprocessor **208** requests the valve operating information **218** from one or more of the valves, but preferably from each valve in the system **200**. The information **218** is processed to determine one or more operating parameters for the variable speed drive **206**, which runs the pump **204** to maintain a desired amount of fluid flow through the system **200**. The result of the speed determination algorithm is fed into a temperature optimization algorithm within the microprocessor **208** to determine the appropriate temperature of the process fluid and forward that temperature information to the appropriate component, such as the

chiller/boiler **202**. Conversely, in alternate embodiments, a temperature optimization algorithm within the microprocessor **208** generates results which are then provided to the speed determination algorithm to determine the appropriate temperature of the process fluid and forward that temperature information to the appropriate component, such as the chiller/boiler **202**.

(17) The microprocessor **208** determines which valves **212** are being commanded to fully open, but are not yet fully open due to valve self-ranging. In addition, the microprocessor **208** determines if the pump speed is low enough in that it would be more efficient to increase the speed to the pump than to adjust the set point to the chiller or boiler **202**. If so, then the microprocessor **208** provides a signal to change a threshold temperature of one or more of the valves **212** to selectively increase fluid flow. If the reverse is true, the set-point temperature of the fluid is adjusted to provide more energy per unit of fluid. Generally, anytime one of the fluid paths includes a valve with its threshold temperature adjusted beyond an initial setting and the fluid does not require additional cooling, then its threshold temperature may be slowly restored to its normal, nominal or original setting. If the microprocessor **208** does not determine that any of the valves **212** are being commanded to fully open and determines that it is more efficient to reduce energy within the system, then the fluid temperature of the system **200** may be slowly adjusted to increase an overall efficiency of the system **200**.

(18) As one or more of the valves **212** open, the microprocessor **208** determines that there is more demand for process fluid in the system **200**, and subsequently provides a signal to the variable speed drive **206** to increase the pump speed to meet the fluid flow demand. The result of one algorithm may be accessed by another algorithm within the microprocessor **208**, where the latter algorithm determines the appropriate temperature of the process fluid. Conversely, as one or more of the valves **212** close, the microprocessor **208** may determine that there is less demand for process fluid in the system **200**, and subsequently provides a signal to the variable speed drive **206** to decrease the pump speed to reduce power while still providing an appropriate amount of fluid flow through the system **200**.

(19) FIG. **4** shows a flow diagram for an algorithm **300** used to control a hydronic distribution system, such as those described above, according to an embodiment of the present invention. At step **302**, data is obtained from a plurality of self-regulating valves arranged in a network and the data is provided to a valve position monitoring module **304** that monitors the self-regulating valves based on the data and based on various feedback signals. At step **306**, true (e.g., real time) valve positions are obtained from one or more of the self-regulating valves. At step **308**, the valve position monitoring module **304** determines whether the position of one or more of the self-regulating valves is increasing (e.g., opening). If yes, then at step **310** the valve position monitoring module **304** provides a signal to one or more pumps to increase the pump speed by a desired amount in correspondence with the increase of valve position. If no, meaning the position of one or more of the self-regulating valves is not increasing, then at step **312** the processor determines whether the valve position is decreasing (e.g., closing). If yes for step **312**, then at step **314** the processor provides a signal to one or more pumps to decrease the pump speed by a desired amount in correspondence with the decrease of valve position.

(20) Contemporaneously at step **316**, data from one or more pumps is obtained and provided to a pump speed module **318**. At step **320**, the pump speed module determines whether it is more efficient to decrease a process set-point temperature. If yes, then at step **322** a signal or other communication is provided to the system to decrease the process set-point temperature. If no at step **320**, then at step **324** the pump speed module determines whether it is more efficient to increase the process set-point temperature. If yes, then at step **326** a signal or other communication is provided to the system to increase the process set-point temperature. If no at step **324** then the module **318** runs through the process again.

(21) At step **328**, a pump add or delete module utilizes information from the valve position monitoring module **304** and the networked pump data **316** to determine whether additional pumps

need to be brought online or taken offline. At step **330**, the pump add or delete module determines whether an additional pump should be brought online to increase the efficiency of the system. If yes, then at step **332** the additional one or more pumps are brought online. At step **334**, the pump add or delete module determines whether on or more pumps should be taken offline to increase the efficiency of the system. If yes, then at step **336** one or more pumps are brought offline.

(22) While the preferred embodiment of the invention has been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment. Instead, the invention should be determined entirely by reference to the claims that follow.

Claims

1. A non-transitory computer-readable medium on which are stored program code that, when executed by a microprocessor, cause the microprocessor to perform a method of controlling a hydronic distribution system using a process fluid for heating or cooling, the method comprising: obtaining in real time valve operating information from one or more of a plurality of self-regulating valves arranged in a network for controlling an amount of fluid to a plurality of coils; executing a speed determination algorithm which processes the valve operating information to determine a desired speed for one or more pumps to maintain a desired amount of process fluid flow through the hydronic distribution system; and using the desired speed for the one or more pumps for setting a speed of the one or more pumps.

2. The non-transitory computer-readable medium according to claim 1, wherein the method further comprises executing a temperature optimization algorithm to determine temperature information for the process fluid, and using the determined temperature information for setting a temperature of the process fluid.

3. The non-transitory computer-readable medium according to claim 2, wherein the temperature information is determined from a result of the speed determination algorithm.

4. The non-transitory computer-readable medium according to claim 2, wherein the method further comprises providing results from the temperature optimization algorithm to the speed determination algorithm.

5. The non-transitory computer-readable medium according to claim 2, wherein the method further comprises adjusting a speed of one or more pumps based on the set speed, if adjusting the speed is more efficient than adjusting a temperature set point based on the set temperature, and adjusting the temperature, if adjusting the temperature is more efficient than adjusting the speed.

6. The non-transitory computer-readable medium according to claim 2, wherein the method further comprises forwarding the temperature information to a component that generates the temperature of the process fluid.

7. The non-transitory computer-readable medium according to claim 2, wherein the method further comprises forwarding the temperature information to a chiller or a boiler.

8. The non-transitory computer-readable medium according to claim 2, wherein the method further comprises bringing the one or more pumps online or offline.

9. The non-transitory computer-readable medium according to claim 1, wherein a result of the speed determination algorithm includes one or more operating parameters for variable speed drives which run the one or more pumps, to maintain the desired amount of process fluid flow.

10. The non-transitory computer-readable medium according to claim 1, wherein the valve operating information includes one or more of a position from one or more of the plurality of self-regulating valves and a fluid temperature of the process fluid leaving one or more of the plurality of self-regulating valves.

11. The non-transitory computer-readable medium according to claim 1, wherein the method

further comprises processing the valve operating information to determine one or more operating parameters for variable speed drives running the one or more pumps.

12. The non-transitory computer-readable medium according to claim 1, wherein the valve operating information includes operating information from each of the one or more of the plurality of self-regulating valves.

13. A system for controlling a hydronic system for heating or cooling, the system including a plurality of self-regulating valves arranged in a network for controlling an amount of fluid to a plurality of coils, one or more pumps, a chiller and/or a boiler, and a microprocessor configured to at least: obtain in real time valve operating information from one or more of the plurality of self-regulating valves; execute a speed determination algorithm which processes the valve operating information to determine a desired speed of the one or more pumps to maintain a desired amount of process fluid flow through the system; and use the desired speed for the one or more pumps for setting a speed of the one or more pumps.

14. The system according to claim 13, wherein the microprocessor is further configured to execute a temperature optimization algorithm to determine temperature information for the fluid, and use the determined temperature information for setting a temperature of the fluid.

15. The system according to claim 14, wherein the temperature information is determined from a result of the speed determination algorithm.

16. The system according to claim 13, wherein a result of the speed determination algorithm includes one or more operating parameters for variable speed drives which run the one or more pumps, to maintain the desired amount of process fluid flow.

17. The system according to claim 13, wherein the valve operating information includes one or more of a position from one or more of the plurality of self-regulating valves and a fluid temperature of the fluid leaving one or more of the plurality of self-regulating valves.

18. A non-transitory computer-readable medium on which are stored program code that, when executed by a microprocessor, cause the microprocessor to perform at least: obtaining, in real time, valve operating information from one or more of a plurality of valves arranged in a network of a hydronic distribution system; executing a speed determination algorithm which processes the valve operating information to determine a desired speed for one or more pumps to maintain a desired amount of process fluid flow of a process fluid to a plurality of coils; and setting a speed of the one or more pumps, based on the desired speed for the one or more pumps that is determined.

19. The non-transitory computer-readable medium according to claim 18, wherein the microprocessor is further configured to execute a temperature optimization algorithm to determine temperature information for the process fluid, and set a temperature of the process fluid based on the determined temperature information.

20. The non-transitory computer-readable medium according to claim 19, wherein the temperature information is determined from a result of the speed determination algorithm.