

SYSTEM AND METHOD FOR OPTIMIZATION OF AIRSIDE EFFICIENCY OF AIR HANDLING UNIT

Related Application

[0001] The present application claims priority to and the benefit of Singapore Patent Application 10202303561Q, filed 19 December 2023, which is hereby incorporated by reference in its entirety.

Technical Field

[0002] The present invention relates to a Heating, Ventilation, and Air Conditioning (HVAC) system and its associated control method, and more particularly, an air handling unit (AHU) system and its control method of optimizing its airside efficiency in a building space.

Background

[0003] An AHU is an essential element of a building's HVAC system, responsible for circulating and regulating air within the building's heating, cooling, and ventilation systems. Specifically, an AHU draws in outside air, mixes it with recirculating air, conditions it according to the set parameters, and distributes it throughout the building. To cool the air, the AHU passes the mixed air through cooling coils, removing the heat and moisture. Subsequently, a fan within the AHU pushes the cooled air into the ductwork of the building, distributing it to various rooms as needed.

[0004] Audits of AHUs show that currently, 90% of AHUs in buildings in Singapore are operating with efficiencies above the optimal 0.15 kW/RT, indicating significant potential for improvement. Investigations suggest that the following factors contribute to such underperformance.

[0005] Firstly, the excessive safety margins on control limits set during initial configurations of AHU contribute to this inefficiency. Additionally, optimal settings for maintaining efficient AHU performance, which are typically based on the experience of system integrators, often lead to energy wastage.

- [0006] Secondly, operational changes that impact AHU efficiency often occur without the necessary technology to adapt to optimal performance under varying working conditions.
- [0007] Thirdly, the limitations of controller facilities, particularly in terms of optimization features, are evident in the lack of effective methods to adjust fan speed while maintaining thermal comfort. Consequently, finding the optimal settings for space conditions relies on a trial-and-error approach. This inefficiency can lead to energy wastage and hinder the overall performance of the system.
- [0008] Fourth, conventional AHU controllers lack the continuous measurement capabilities necessary for detailed analytics.
- [0009] Fifthly, the absence of an efficiency performance indicator means that the total system efficiency of the HVAC system is currently not optimized.
- [0010] To address the above and other issues, there is a need for an AHU system and an associated control method that may effectively uphold AHU efficiency, especially in temperate countries where air-conditioning loads vary significantly with seasonal changes.

Summary of Invention

- [0011] Embodiments of the invention provide for a computer-implemented method and a system for optimizing operating airside efficiency of an AHU which are advantageous over existing methods by delivering a systematic and dynamic flow that adapts to various operating and spatial conditions. This adaptation may allow the AHU to modulate its cooling and heating capacities to match the climatic conditions in temperate regions while maintaining peak efficiency. Ultimately, this may enhance the optimization of the AHU system and ensure optimal Total System Efficiency for the entire HVAC system.
- [0012] According to an embodiment, a computer-implemented method is provided for optimizing operating efficiency of an AHU which regulates airflow into a building space. The method comprises a step of regulating a chilled water valve of the AHU to achieve a present temperature of supply airflow being set at a minimum setpoint temperature of supply airflow. The chilled water valve is arranged at a chilled water pipe and is configured to control the present temperature of supply airflow by regulating amount of chilled water flowing from the chilled water pipe into coils of the AHU. The method yet includes a step of operating a fan of the AHU at a present fan speed to achieve a maximum setpoint of

total static pressure of supply airflow. The method yet further includes a step of performing iterations of the following steps:

[0013] A step of comparing a present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present temperature of return airflow is above the initial setpoint temperature of return airflow, the method performs that comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow. While the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, the method performs reducing an initial setpoint temperature of supply airflow. The reduced initial setpoint temperature is to be set as the initial setpoint temperature of supply airflow for a subsequent one of the iterations, e.g. next iteration. While the present temperature of supply airflow is at the minimum setpoint temperature of supply airflow, the method performs increasing an initial setpoint of total static pressure of supply airflow by increasing the present fan speed. The increased initial setpoint of total static pressure of supply airflow is to be set as the initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations. The increased fan speed is maintained below a maximum fan speed.

[0014] The step of comparing the present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present temperature of return airflow is below the initial setpoint temperature of return airflow, the method performs that comparing a present total static pressure of supply airflow with a minimum setpoint of total static pressure. While the present total static pressure of supply airflow is above the minimum setpoint of total static pressure, the method performs that comparing the present fan speed with a minimum setpoint of fan speed. While the present fan speed is above the minimum setpoint speed of the AHU, the method performs that decreasing the initial setpoint of total static pressure of supply airflow by reducing the present fan speed. The decreased setpoint of total static pressure of supply airflow is to be set as the initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations. While the present fan speed is at the minimum setpoint speed of AHU, the method performs that maintaining the present fan speed and that comparing a present relative humidity of

return airflow / intake entering the AHU with the maximum setpoint of relative humidity return airflow / intake entering the AHU and increasing the initial setpoint temperature of the supply airflow when the present relative humidity of return airflow / intake entering AHU / intake entering the AHU is below the maximum setpoint of relative humidity of return airflow/ intake entering the AHU. The increased initial setpoint temperature of supply airflow is to be set as the initial setpoint for the subsequent one of the iterations.

[0015] The step of comparing the present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present total static pressure of supply airflow is at the minimum setpoint of total static pressure, the method performs that comparing the present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow. While the present relative humidity of return airflow / intake entering the AHU is below or at the maximum setpoint of relative humidity of return airflow / intake entering the AHU, the method performs that increasing the initial setpoint temperature of the supply airflow by regulating the chilled water valve. The increased initial setpoint temperature of the supply airflow is set to be the initial setpoint temperature of the supply airflow for the next step. While the present relative humidity of return airflow / intake entering the AHU is above the maximum setpoint of relative humidity of return airflow / intake entering the AHU, the method performs maintaining the present total static pressure.

[0016] According to an embodiment, a system is provided for optimizing operating efficiency of an AHU which is configured to regulate airflow to a building space. The system comprises a first thermal sensor arranged at a return airflow duct for measuring a present temperature of a return airflow, a second thermal sensor arranged at a supply airflow duct for measuring a present temperature of a supply airflow, a relative humidity sensor configured to measure a present relative humidity of return airflow / intake entering the AHU, a pressure transmitter configured to measure a present total static pressure of the supply airflow, a chilled water valve configured to control the present temperature of the supply airflow by regulating amount of chilled water into coils of the AHU, a variable speed drive (VSD)

configured to modulate a present fan speed of the AHU, an optional digital power meter (DPM) configured to measure a present fan operating power.

[0017] The system yet includes a memory that is configured to store computer or controller-executable instructions, and data obtained by the first thermal sensor, the second thermal sensor, the humidity sensor, the pressure transmitter, the valve, the variable speed drive, and the digital power meter.

[0018] The system yet further includes a computer processor or controller which is communicably coupled to the first thermal sensor, the second thermal sensor, the relative humidity sensor, the pressure transmitter, the valve, the variable speed drive to receive data therefrom, and the digital power meter, and communicably coupled to the memory and configured to execute the instructions stored in the memory to perform the following (first) steps:

[0019] A step of regulating a chilled water valve of the AHU to achieve the present temperature of supply airflow being set at a minimum setpoint temperature of supply airflow. The chilled water valve is arranged at a chilled water pipe and is configured to control the present temperature of supply airflow by regulating amount of chilled water flowing from the chilled water pipe into coils of the AHU.

[0020] The instructions stored in the memory include performing the step of operating a fan of the AHU at a present fan speed to achieve a maximum setpoint of total static pressure. The instructions yet further include performing iterations of the following (second) steps:

[0021] A step of comparing a present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present temperature of return airflow is above the initial setpoint temperature of return airflow, the following step(s) are performed: comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow. While the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, the following step(s) are performed: reducing an initial setpoint temperature of supply airflow. The reduced initial setpoint temperature is to be set as the initial setpoint temperature of supply airflow for a subsequent one of the iterations. While the present temperature of supply airflow is at the minimum setpoint temperature of supply airflow, the following step(s) are performed: increasing an initial setpoint of total static pressure of supply airflow by increasing the present fan speed. The

increased initial setpoint of total static pressure of supply airflow is to be set as the initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations. The increased fan speed is maintained below a maximum fan speed.

[0022] The step of comparing the present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present temperature of return airflow is below the initial setpoint temperature of return airflow, the following step(s) are performed: comparing a present total static pressure with a minimum setpoint of total static pressure. While the present total static pressure is above the minimum setpoint of total static pressure, the following step(s) are performed: comparing the present fan speed with a minimum setpoint of fan speed. While the present fan speed is above the minimum setpoint speed of the AHU, the following step(s) are performed: decreasing the initial setpoint of total static pressure by reducing the present fan speed. The decreased setpoint of total static pressure is to be set as the initial setpoint of total static pressure for the subsequent one of the iterations. While the present fan speed is at the minimum setpoint speed of AHU, the following step(s) are performed: maintaining the present fan speed and comparing a present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow / intake entering the AHU, and the following step(s) are performed: increasing the initial setpoint temperature of the supply airflow when the present relative humidity of return airflow / intake entering the AHU is below the maximum setpoint of relative humidity of return airflow / intake entering the AHU. The increased initial setpoint temperature of supply airflow is to be set as the initial setpoint for the subsequent one of the iterations, e.g., next iteration.

[0023] The step of comparing the present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present total static pressure is at the minimum setpoint of total static pressure, the following step(s) are performed: comparing the present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow / intake entering the AHU. While the present relative humidity of return airflow / intake entering the AHU is below or at the maximum setpoint of relative humidity

of return airflow / intake entering the AHU, the following step(s) are performed: increasing the initial setpoint temperature of the supply airflow by regulating the chilled water valve. The increased initial setpoint temperature of the supply airflow is set to be the initial setpoint temperature of the supply airflow for the next step. While the present relative humidity of return airflow / intake entering the AHU is above the maximum setpoint of relative humidity of return airflow / intake entering the AHU, the following step(s) are performed: maintaining the present total static pressure of supply airflow.

[0024] The computer-implemented method and system may offer several advantages for AHUs. By minimizing human intervention and automatically determining the optimal setpoint for total static pressure of supply airflow, this method and system may eliminate the inefficient trial-and-error process commonly associated with current methods and systems. The auto-adjustments of the method and the system may ensure maximum airside efficiency and maintain thermal comfort within building spaces. Crucially, the present method and system may also prevent the oversupply of fan power while preserving minimal airflow, thanks to precise setpoint control. Additionally, by applying the fan affinity law, the system dynamically adjusts total static pressure of supply airflow based on real-time conditions, allowing for the selection of appropriate fan speeds that optimize operations. These adjustments not only improve operational efficiency but also significantly reduce power consumption, leading to enhanced energy savings for the AHU system.

Brief Description of Drawings

[0025] In the drawings, like reference characters generally refer to like parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments of the invention are described with reference to the following drawings, in which:

[0026] FIG. 1 is a schematic diagram illustrating the installation and hardware components of a general AHU system, according to various embodiments.

[0027] FIG. 2 is a schematic diagram illustrating a method for optimizing operating efficiency of an AHU that regulates airflow to a building space, according to various embodiments.

[0028] FIG. 3 is a schematic diagram illustrating an operating interface of the AHU system of FIG. 1, according to various embodiments.

[0029] FIG. 4 is a schematic diagram illustrating an operating interface of the AHU system of FIG. 1, according to various embodiments.

Detailed Description

[0030] The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in art to practice the invention. Other embodiments may be utilized, and structural, logical, and electrical changes may be made without departing from the scope of the invention. The various embodiments are not necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments.

[0031] Embodiments described in the context of one of the systems are analogously valid for the other systems.

[0032] Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments. Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0033] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0034] As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0035] In the context of various embodiments, the phrases “adapted to”, “configured to” and “arranged to” may be used interchangeably.

[0036] Various embodiments provide a computer-implemented method for optimizing operating efficiency of an AHU which regulates airflow to a building space. The method may enable

AHU to achieve and maintain healthy operating parameters while minimizing the power consumption of its fan.

[0037] FIG. 1 is a schematic diagram illustrating the installation and hardware components of a general AHU system 100. The AHU system 100 is integrated with a variety of sensors and a computer processor or controller 118 to optimize its operation, according to various embodiments of the present invention.

[0038] Referring to FIG. 1, the main body of system 100 is the AHU 102, where the airflow management process occurs. Air may be drawn into the AHU 102 from the building space. This could be a mix of fresh external air and recirculated internal air. The air intake may further be conditioned. As the air moves through the AHU 102, it passes through various conditioning processes. These could involve cooling or heating, humidifying, or dehumidifying the air, depending on the system's setup and the feedback received from the environmental sensors like the relative humidity (RH) and return airflow temperature sensors.

[0039] As the air flows through the AHU system 100, its properties are continuously monitored by the sensors. For example, the return airflow temperature sensor 104 measures the present temperature of the return airflow (RA). The relative humidity sensor 106 checks the present relative humidity level of the return airflow or intake entering the AHU. The supply airflow temperature sensor 108 monitors the present temperature of the supply airflow (SA) as it is prepared to be sent out into the building space. The enthalpy sensor 110 measures the total heat content of the air, which helps determine how much energy is required for conditioning. The pressure differential sensor 114 detects the present total static pressure (TSP) of the supply airflow. The tachometer sensor checks the present fan speed.

[0040] The pressure differential sensor 114 manages the total static pressure of supply airflow within the AHU system 100, ensuring the pressure in the building space is within safe and effective operating limits. The pressure differential sensor 114 particularly helps in monitoring the pressure difference across the AHU system 100 which may indicate the condition of filters or other obstructions.

- [0041] The variable speed drive 116 controls the present speed of the fan based on the setpoint of total static pressure of supply airflow. This is adjusted to ensure efficient energy use while maintaining optimal airflow as dictated by the AHU system 100's current demands.
- [0042] Based on feedback from the sensors and computer processor or controller 118 of the AHU system 100, the chilled water valve 120 is adjusted to regulate the setpoint temperature of supply airflow, ensuring that the air delivered into the building space meets the desired conditions. The computer processor or controller 118 will manage the variable speed drive 116 and the modulating chilled water valve 120. The array of sensors outlined above will be deployed, with a digital power meter 122 connected to the computer processor or controller 118 for measuring a present fan operating power. With feedback on the fan speed displayed on the variable speed drive 116 and the measurements from modulating the chilled water valve 120, the computer processor or controller 118 may send signals to adjust the chilled water valve 120. This adjustment maximizes the cooling coil 124's effectiveness, achieving a lower supply airflow temperature to enhance moisture removal. Simultaneously, it uses the present return airflow temperature to modulate the motor speed, thereby reducing the present total static pressure setpoint of of supply airflow.
- [0043] Once conditioned, the return airflow is pushed by the fan through ductwork out into various parts of the building space, entering as supply airflow at the temperature measured by the supply air temperature sensor 108.
- [0044] The entire process is continuously adjusted based on real-time data from the digital power meter 122 and feedback loops to the computer processor or controller 118. This ensures the AHU system 100 operates optimally, adjusting the fan speed, chilled water valve 120 positions, and other settings to efficiently meet the building's current environmental needs.
- [0045] FIG. 2 is a schematic diagram illustrating method 200 for optimizing operating efficiency of an AHU (FIG. 1, 102) that regulates airflow to a building space, according to various embodiments.
- [0046] Referring to FIG. 2, method 200 employs a combination of three control loops: a chilled water valve control loop, supply airflow control loop, and a total static pressure control loop. Operated by computer implementation, method 200 continuously monitors and adjusts the setpoint temperature of supply airflow and setpoint total static pressure of supply airflow. These setpoints may be dynamically adjusted during iterations of the loops.

According to FIG.1, the chilled water valve 120 is arranged at a chilled water pipe 126 and configured to control the present temperature of supply airflow by regulating the amount of chilled water flowing from the chilled water pipe 126 into coils 124 in the AHU.

[0047] As shown in FIG. 2, method 200 not only employs three control loops but also establishes initial boundary limits for various parameters. These include the setpoint temperature of return airflow; minimum and maximum setpoint temperatures of supply airflow; minimum and maximum fan speeds; minimum and maximum opening percentage of the chilled water valve (FIG.1, 120) (may be expressed as percentage values based on full flow capacity of the chilled water valve (FIG.1, 120)); minimum and maximum setpoints for total static pressure of supply airflow; maximum relative humidity of return airflow / intake entering the AHU; adjustable value step for setpoint of total static pressure of supply airflow, and adjustable value step for supply airflow setpoint temperature. The setpoint temperature of return airflow is pre-determined and may not be auto-adjusted during the loops.

[0048] For example, the initial setpoint temperature of return airflow may be set at 24°C, with the minimum and maximum setpoint temperatures of supply airflow set at 14°C and 17°C, respectively. Furthermore, the minimum setpoint for fan speed may be set at 25Hz, and the maximum setpoint at 45Hz. The minimum and maximum fan speeds may prevent motor malfunction and may reduce noise levels and prevent the building from operating over the contracted electrical maximum demand.

[0049] The minimum percentages of the chilled water valve (FIG.1, 120) may be set at 30% of its full flow capacity, with the maximum opening at 80%. The total static pressure of supply airflow may be set with minimum and maximum setpoints at 500Pa and 1000Pa, respectively. The maximum relative humidity of return airflow / intake entering the AHU may be set at 70%. Similarly, these above-mentioned control limits are pre-determined prior to the loops start, they will not be modified during the loops. However, these control limits may be adjusted before the loops are activated.

[0050] The exemplary preset boundary limits are influenced by various factors, including operating requirements, safety risks, design constraints, and the need to prevent high fluctuations, and the limitations imposed by the equipment. These settings are essential for ensuring the AHU operates within a controlled range, which enhances indoor air quality and operational efficiency. Additionally, they help to improve water balance in the

hydraulic system, optimizing pump energy usage and thereby enhancing the overall performance of the air-conditioning system, which includes chillers and pumps.

- [0051] As per the chilled water control loop, as shown in FIG.2, it includes steps A to E. The chilled water control loop regulates a chilled water valve (FIG.1, 120) of the AHU with an objective to achieve a present temperature of supply airflow being set at a minimum setpoint temperature of supply airflow. Specifically, the regulation of the chilled water valve (FIG.1, 120) includes steps of measuring the present temperature of supply airflow and comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow.
- [0052] While the present temperature of supply airflow is above the initial minimum setpoint temperature of supply airflow, before commanding the chilled water valve (FIG.1, 120) to open, the method 200 first examines if modulating the chilled water valve (FIG.1, 120) has reached the maximum opening condition of the chilled water valve (step A). For example, this may be conducted by comparing a present opening of the chilled water valve (FIG.1, 120) with a maximum opening limit of the chilled water valve (FIG.1, 120).
- [0053] While the present opening of the chilled water valve (FIG.1, 120) corresponds to the maximum opening of the chilled water valve (FIG.1, 120), the method includes maintaining the chilled water valve (FIG.1, 120) at the present opening and prompting a user, via an operating interface, to check the present opening of the chilled water valve (step B).
- [0054] Step C includes verifying an opening command of the chilled water valve (FIG.1, 120), e.g. computed percentage values based on full flow capacity of chilled water valve (FIG.1, 120) as ascertained by a computer processor against an opening of the chilled water valve (FIG.1, 120) as measured. While the opening command of the chilled water valve (FIG.1, 120) as ascertained by a computer processor differs from the opening of the chilled water valve (FIG.1, 120), prompting a user, via an operating interface, to check the present opening of the chilled water valve (FIG.1, 120). While the present opening of the chilled water valve (FIG.1, 120) is narrower than the maximum opening of the chilled water valve (FIG.1, 120), the method includes enlarging the present opening of the chilled water valve (step D).

- [0055] These adjustments in valve opening may be monitored and controlled by computer processor. Occasionally, adjustments to the minimum and maximum setpoint temperatures of the supply airflow may be necessary due to site conditions or weather fluctuations, particularly in temperate countries. The extent of setpoint temperature of supply airflow fluctuation will depend on the specific application used in each building. Similarly, adjustments to setpoints of various parameters may be monitored and controlled by a computer processor.
- [0056] While the present temperature of supply airflow is below or equal to the minimum setpoint temperature of supply airflow, the method includes performing closing of the opening of the chilled water valve (FIG.1, 120) (step E). For example, the supply air temperature sensor (FIG. 1, 108) detects if the present supply airflow temperature has reached 14°C. This will trigger the opening or closing of the chilled water valve (FIG.1, 120) based on the setpoint temperature of the supply airflow. When the present supply airflow temperature is higher than its initial setpoint temperature, before commanding the chilled water valve (FIG.1, 120) to open, the method 200 includes examining if modulating chilled water valve (FIG.1, 120) has reached the maximum position 80%.
- [0057] Once the chilled water valve loop is activated. The method 200 is in normal daily operation, the return airflow control loop and total static pressure control loop will be activated.
- [0058] As illustrated by Steps F to N in FIG.2, the initial setpoint temperature of return airflow is exemplarily set for instance at 24°C, with the minimum setpoint temperature of supply airflow exemplarily set at 14°C. A fan of the AHU is operated at a present fan speed to achieve a maximum setpoint of total static pressure of supply airflow, exemplarily at 45Hz. The method 200 performs iterations of the following steps:
- [0059] The method includes comparing the present temperature of return airflow with an initial setpoint temperature of return airflow (step F). While the present temperature of return airflow is above the initial setpoint temperature of return airflow, the method includes comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow (step G). While the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, the method includes reducing the initial setpoint temperature of supply airflow (step H). For example, the initial setpoint temperature of supply airflow is reduced by a pre-determined step of value – 0.1 °C. The

reduced initial setpoint temperature is to be set as the new initial setpoint temperature of supply airflow for a subsequent one of the iterations, e.g., next iteration.

[0060] While the present temperature of supply airflow is at the minimum setpoint temperature of supply airflow, the method includes increasing an initial setpoint of total static pressure of supply airflow by increasing the present fan speed (step I). For example, the increment of initial setpoint of total static pressure of supply airflow is exemplarily set as 10Pa. The increased initial setpoint of total static pressure of supply airflow is to be set as the new initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations. The increased fan speed is maintained below a maximum fan speed.

[0061] The step of comparing the present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present temperature of return airflow is below the initial setpoint temperature of return airflow, the method includes comparing a present total static pressure of supply airflow with a minimum setpoint of total static pressure of supply airflow (step J). While the present total static pressure of supply airflow is above the minimum setpoint of total static pressure of supply airflow, the method includes comparing the present fan speed with a minimum setpoint of fan speed (step K). While the present fan speed is above the minimum setpoint speed of the AHU, the method includes decreasing the initial setpoint of total static pressure of supply airflow by reducing the present fan speed (step L). An exemplary reducing step is 10Pa. The decreased setpoint of total static pressure of supply airflow is to be set as the new initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations. While the present fan speed is at the minimum setpoint speed of AHU (step M), the method includes maintaining the present fan speed and comparing present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow / intake entering the AHU, i.e., 70%, and increasing the initial setpoint temperature of the supply airflow when the present relative humidity of return airflow / intake entering the AHU is below the maximum setpoint of relative humidity of return airflow / intake entering the AHU (step N). An exemplary increment of setpoint temperature is 0.1°C. The increased initial setpoint temperature of supply airflow is to be set as the new initial setpoint for the subsequent one of the iterations.

[0062] The step of comparing the present temperature of return airflow with an initial setpoint temperature of return airflow is performed. While the present total static pressure of supply airflow is at the minimum setpoint of total static pressure of supply airflow, the method includes comparing the present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow / intake entering the AHU (step M). While the present relative humidity of return airflow / intake entering the AHU is below or at the maximum setpoint of relative humidity of return airflow / intake entering the AHU, the method includes increasing the initial setpoint temperature of the supply airflow by regulating the chilled water valve (FIG. 1, 120) (step N). An exemplary increasement of setpoint temperature is 0.1°C. The increased initial setpoint temperature of the supply airflow is set to be the initial setpoint temperature of the supply airflow for the next iteration. While the present relative humidity of return airflow / intake entering the AHU is above the maximum setpoint of relative humidity of return airflow / intake entering the AHU, the method includes maintaining the present total static pressure of supply airflow.

[0063] FIG. 3 is a schematic diagram illustrating an operating interface of the AHU system of FIG. 1, according to various embodiments. The operating interface of FIG. 3 displays parameters, including but not limited to, the present temperature of return airflow, the present temperature of supply airflow, relative humidity of return airflow / intake entering the AHU, current opening percentages of the chilled water valve, and present total static pressure of the supply airflow.

[0064] FIG. 4 is a schematic diagram, illustrating an operating interface of the AHU system of FIG. 1, according to various embodiments. The operating interface of FIG. 4 displays parameters, including but not limited to, the setpoint temperature of return airflow, the initial setpoint temperature of supply airflow, and the initial setpoint of total static pressure of supply airflow. Notably, the initial setpoint temperatures of supply airflow and the initial setpoint of total static pressure of supply airflow are dynamic, adjusting through iterations, while the setpoint temperature of return airflow remains fixed. The dynamic changes are displayed and presented to a human user via the operating interface.

[0065] The method further includes a belt checking to enhance user friendliness by helping identify the total static pressure baseline of supply airflow upon tightening an AHU belt

pulley 123. This function allows operators to detect a loose belt pulley (FIG. 1, 123) by comparing the present total static pressure of supply airflow displayed against the baseline measurements established during a belt test. To conduct the belt test, users tighten the belt pulley (FIG. 1, 123), access the belt test function on the AHU, and initiate a test at a preset motor speed of 80% (adjustable) for 10 minutes. The computer processor records the motor speed during the belt test, total static pressure of supply airflow during the belt test, and test date, providing baseline total static pressure measurements of supply airflow established during the belt test. Users can then regularly compare current total static pressure data—shown in values and graphs—with these baselines to identify if the belt pulley (FIG. 1, 123) is loose.

- [0066] The method identifies the baseline total static pressure of supply airflow by tightening the belt pulley (FIG. 1, 123) on the AHU. If the present total static pressure of supply airflow falls below baseline total static pressure of supply airflow, the belt pulley (FIG. 1, 123) is identified as being loose. Additionally, the method detects the carbon dioxide (CO₂) composition in the return airflow and regulates the fresh air composition in the supply airflow based on how this CO₂ composition compares to a predetermined threshold.
- [0067] The present invention provides an AHU method/system that surpasses the rigid structure of the conventional Building Management System (BMS), which primarily relies on monitoring return airflow temperature and fixed supply airflow temperature setpoints. Typically, any deviation in return airflow temperature in a conventional BMS requires manual adjustment of the supply airflow temperature setpoint and continuous visual monitoring to fine-tune as needed. The present invention minimizes human intervention by concurrently managing both return airflow temperature and total static pressure of supply airflow. The computer-implemented flow sequence or algorithm continually loops back at the end of the process to simultaneously recheck the conditions of both return and supply air temperatures against their setpoints. This integrated approach distinguishes the present invention from conventional methods, making it uniquely effective.
- [0068] This results in dynamic loop(s) within the entire flowchart, characterized by real-time changes in operating parameters that optimize AHU performance and drive toward high Total Air-Conditioning System Efficiency. The invention utilizes a Smart Algorithm to maximize airside efficiency and enhance the Total System Efficiency of the entire ACMV

systems. Designed with real-time responsiveness, the system sets all necessary parameters for energy efficiency and occupant comfort, as illustrated in the chart below. Additionally, this invention can augment the BMS approach by addressing its limitations in airside efficiency across ACMV systems.

[0069] The flow charts showing logic flow may be implemented in software, firmware, hardware, or any combination thereof. In software and firmware embodiments, the logic flow may be implemented by computer executable instructions or code stored on a non-transitory computer-readable medium or machine-readable medium, such as an optical, magnetic or semiconductor storage. The computer-executable instructions are configured to direct at least one computer processor to perform the logic flow. The embodiments are not limited in this context.

[0070] The processor may be any type of computer processor, such as a microprocessor, an embedded processor, a digital signal processor (DSP), a network processor, a multi-core processor, a single core processor, or other device configured to execute code or computer-executable instructions to perform or implement the flowcharts, algorithms, processes, or operations detailed herein. The memory may be a non-transitory computer-readable medium or machine-readable medium for storing or comprising the code or computer-executable instructions. Examples include, but are not limited to, random access memory (RAM), read-only memory (ROM), logic blocks of a field programmable gate array (FPGA), erasable programmable read-only memory (EPROM), and electrically erasable programmable ROM (EEPROM).

[0071] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims and therefore intended to be embraced.

Claims

1. A computer-implemented method of optimizing operating efficiency of an air handling unit (AHU) which regulates airflow to a building space, the method comprising:

regulating a chilled water valve of the AHU to achieve a present temperature of supply airflow being set at a minimum setpoint temperature of supply airflow, wherein the chilled water valve is arranged at a chilled water pipe and configured to control the present temperature of supply airflow by regulating amount of chilled water flowing from the chilled water pipe into coils of the AHU;

operating a fan of the AHU at a present fan speed to achieve a maximum setpoint of total static pressure of supply airflow;

performing iterations of the following steps:

comparing a present temperature of return airflow with an initial setpoint temperature of return airflow;

while the present temperature of return airflow is above the initial setpoint temperature of return airflow, performing:

comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow;

while the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, reducing an initial setpoint temperature of supply airflow, wherein the reduced initial setpoint temperature is to be set as the initial setpoint temperature of supply airflow for a subsequent one of the iterations;

while the present temperature of supply airflow is at the minimum setpoint temperature of supply airflow, increasing an initial setpoint of total static pressure of supply airflow by increasing the present fan speed, wherein the increased initial setpoint of total static pressure of supply airflow is to be set as the initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations, and wherein the increased fan speed is maintained below a maximum fan speed;

while the present temperature of return airflow is below the initial setpoint temperature of return airflow, performing:

comparing a present total static pressure of supply airflow with a minimum setpoint of total static pressure of supply airflow;

while the present total static pressure of supply airflow is above the minimum setpoint of total static pressure of supply airflow, performing:

comparing the present fan speed with a minimum setpoint of fan speed;

while the present fan speed is above the minimum setpoint speed of the AHU, decreasing the initial setpoint of total static pressure of supply airflow by reducing the present fan speed, wherein the decreased setpoint of total static pressure of supply airflow is to be set as the initial setpoint of total static pressure of supply airflow for the subsequent one of the iterations; and

while the present fan speed is at the minimum setpoint speed of AHU, maintaining the present fan speed and comparing a present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow / intake entering the AHU, and increasing the initial setpoint temperature of the supply airflow when the present relative humidity of return airflow / intake entering the AHU is below the maximum setpoint of relative humidity of return airflow / intake entering the AHU, wherein the increased initial setpoint temperature of supply airflow is to be set as the initial setpoint for the subsequent one of the iterations;

while the present total static pressure of supply airflow is at the minimum setpoint of total static pressure of supply airflow, performing:

comparing the present relative humidity of return airflow / intake entering the AHU with the maximum setpoint of relative humidity of return airflow / intake entering the AHU;

while the present relative humidity of return airflow / intake entering the AHU is below or at the maximum setpoint of relative humidity of return airflow / intake entering the AHU, increasing the initial setpoint temperature of the supply airflow by regulating the chilled water valve, wherein the increased initial setpoint temperature of the supply airflow is set to be the initial setpoint temperature of the supply airflow for the subsequent one of the iterations; and

while the present relative humidity of return airflow / intake entering the AHU is above the maximum setpoint of relative humidity of return airflow / intake entering the AHU, maintaining the present total static pressure of supply airflow.

2. The method as claimed in claim 1, wherein regulating a chilled water valve of the AHU to achieve a present temperature of supply airflow at a minimum setpoint temperature of supply airflow comprises:

measuring the present temperature of supply airflow;

comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow;

while the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, performing:

comparing a present opening of the chilled water valve with a maximum opening limit of the chilled water valve;

while the present opening of the chilled water valve corresponds to the maximum opening of the chilled water valve, maintaining the chilled water valve at the present opening;

while the present opening of the chilled water valve is narrower than the maximum opening of the chilled water valve, enlarging the present opening of the chilled water valve;

while the present temperature of supply airflow is below or equal to the minimum setpoint temperature of supply airflow, performing:

closing the opening of the chilled water valve.

3. The method as claimed in claim 2, prior to maintaining the chilled water valve at the present opening while the present opening of the chilled water valve corresponds to the maximum opening of the chilled water valve, the method further comprising:

verifying an opening command of the chilled water valve as ascertained by a computer processor against an opening of the chilled water valve as measured;

while the opening command of the chilled water valve as ascertained by a computer processor differs from the opening of the chilled water valve, prompting a user, via an operating interface, to check the present opening of the chilled water valve.

4. The method as claimed in claim 3, further comprising:

displaying, via the operating interface, the setpoint temperature of return airflow, the initial setpoint temperature of supply airflow, the initial setpoint of total static pressure of supply airflow, wherein the initial setpoint temperature of supply airflow and the initial

setpoint of total static pressure of supply airflow are dynamically adjusted during the iterations, and wherein the setpoint of return airflow is fixed.

5. The method as claimed in any claim of claims 1 to 4, further comprising:

identifying a baseline total static pressure of supply airflow by tightening a belt pulley of the AHU; and

identifying the belt pulley as being in a loose condition when the present total static pressure of supply airflow is lower than the baseline total static pressure of supply airflow.

6. The method as claimed in any claim of claims 1 to 5, further comprising:

recording the initial setpoint of supply airflow and the initial setpoint of total static pressure of supply airflow.

7. The method as claimed in any claim of claims 1 to 6, further comprising:

detecting, by a CO₂ sensor, a CO₂ composition in the return airflow;

based on the CO₂ composition relative to a predetermined threshold;

regulating a fresh air composition in the supply airflow.

8. A system for optimizing operating efficiency of an air handling unit (AHU) which is configured to regulate airflow to a building space, the system comprising:

a first thermal sensor arranged at a return airflow duct for measuring a present temperature of return airflow;

a second thermal sensor arranged at a supply airflow duct for measuring a present temperature of supply airflow;

a relative humidity sensor configured to measure a present relative humidity of return airflow or an intake entering the AHU;

a pressure transmitter configured to measure a present total static pressure of supply airflow;

a chilled water valve configured to control the present temperature of supply airflow by regulating amount of chilled water into coils of the AHU;

a variable speed drive configured to modulate a present fan speed of the AHU;

a memory configured to store computer-executable instructions, and data obtained by the first thermal sensor, the second thermal sensor, the humidity sensor, the pressure transmitter, the chilled water valve, the variable speed drive;

a computer processor or controller communicably coupled to the first thermal sensor, the second thermal sensor, the relative humidity sensor, the pressure transmitter, the chilled water valve, the variable speed drive to receive data therefrom, and communicably coupled to the memory and configured to execute the instructions stored in the memory to perform first steps comprising:

regulating a chilled water valve of the AHU to achieve the present temperature of supply airflow being set at a minimum setpoint temperature of supply airflow, wherein the chilled water valve is arranged at a chilled water pipe and configured to control the present temperature of supply airflow by regulating amount of chilled water flowing from the chilled water pipe into coils of the AHU;

operating a fan of the AHU at a present fan speed to achieve a maximum setpoint of total static pressure;

performing iterations of the following second steps:

comparing the present temperature of return airflow with an initial setpoint temperature of return airflow;

while the present temperature of return airflow is above the initial setpoint temperature of return airflow, performing:

comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow;

while the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, reducing an initial setpoint temperature of supply airflow, wherein the reduced initial setpoint temperature is to be set as the initial setpoint temperature of supply airflow for a subsequent one of the iterations;

while the present temperature of supply airflow is at the minimum setpoint temperature of supply airflow, increasing an initial setpoint of total static pressure by increasing the present fan speed, wherein the increased initial setpoint of total static pressure is to be set as the initial setpoint of total static pressure for the subsequent one of the iterations, and wherein the increased fan speed is maintained below a maximum fan speed;

while the present temperature of return airflow is below the initial setpoint temperature of return airflow, performing:

comparing the present total static pressure with a minimum setpoint of total static pressure;

while the present total static pressure is above the minimum setpoint of total static pressure, performing:

comparing the present fan speed with a minimum setpoint of fan speed;

while the present fan speed is above the minimum setpoint speed of the AHU, decreasing the initial setpoint of total static pressure by reducing the present fan speed, wherein the decreased setpoint of total static pressure is to be set as the initial setpoint of total static pressure for the subsequent one of the iterations; and

while the present fan speed is at the minimum setpoint speed of AHU, maintaining the present fan speed and comparing a present relative humidity of return airflow or an intake entering the AHU with the maximum setpoint of relative humidity of return airflow or an intake entering the AHU, and increasing the initial setpoint temperature of the supply airflow when the present relative humidity of return airflow or an intake entering the AHU is below the maximum setpoint of relative humidity of return airflow or an intake entering the AHU, wherein the increased initial setpoint temperature of supply airflow is to be set as the initial setpoint for the subsequent one of the iterations;

while the present total static pressure is at the minimum setpoint of total static pressure, performing:

comparing the present relative humidity of return airflow or an intake entering the AHU with the maximum setpoint of relative humidity of return airflow or an intake entering the AHU;

while the present relative humidity of return airflow or an intake entering the AHU is below or at the maximum setpoint of relative humidity of return airflow or an intake entering the AHU, increasing the initial setpoint temperature of the supply airflow by regulating the chilled water valve, wherein the increased initial setpoint temperature of the supply airflow is set to be the initial setpoint temperature of the supply airflow for the subsequent one of the iterations; and

while the present relative humidity of return airflow or an intake entering the AHU is above the maximum setpoint of relative humidity of return airflow or an intake entering the AHU, maintaining the present total static pressure.

9. The system as claimed in claim 8, wherein the first steps of regulating a chilled water valve of the AHU to achieve a present temperature of supply airflow at a minimum setpoint temperature of supply airflow include:

measuring the present temperature of supply airflow;

comparing the present temperature of supply airflow with the minimum setpoint temperature of supply airflow;

while the present temperature of supply airflow is above the minimum setpoint temperature of supply airflow, performing:

comparing a present opening of the chilled water valve with a maximum opening limit of the chilled water valve;

while the present opening of the chilled water valve corresponds to the maximum opening of the chilled water valve, maintaining the chilled water valve at the present opening;

while the present opening of the chilled water valve is narrower than the maximum opening of the chilled water valve, enlarging the present opening size of the chilled water valve;

while the present temperature of supply airflow is below or equal to the minimum setpoint temperature of supply airflow, performing:

closing the opening of the chilled water valve.

10. The system as claimed in claim 9, wherein prior to maintaining the chilled water valve at the present opening while the present opening of the chilled water valve corresponds to the maximum opening of the chilled water valve, the second steps further comprise:

verifying a computer-regulated opening of the chilled water valve against a measured opening of the chilled water valve;

while the computer-regulated opening of the chilled water valve differing from the measured opening of the chilled water valve, the method prompting a user, via an operating interface, to check the actual present opening of the chilled water valve.

11. The system as claimed in claim 10, wherein the operating interface comprises display of the setpoint temperature of return airflow, and the initial setpoint temperature of supply airflow, the initial setpoint of total static pressure, wherein the initial setpoint temperature

of supply airflow and the initial setpoint of total static pressure are dynamically adjusted, and wherein the setpoint of return airflow is fixed.

12. The system as claimed in any claim of claims 8 to 11, further comprising:

a belt pulley of the AHU configured to establish a baseline total static pressure, wherein the first steps further comprise:

identifying the baseline total static pressure by tightening the belt pulley of the AHU;
and

identifying the belt pulley as in a loose condition when the present total static pressure is lower than the minimum setpoint of total static pressure.

13. The system as claimed in any claim of claims 8 to 12, wherein the first steps further comprise:

recording the initial setpoint of supply airflow and the initial setpoint of total static pressure.