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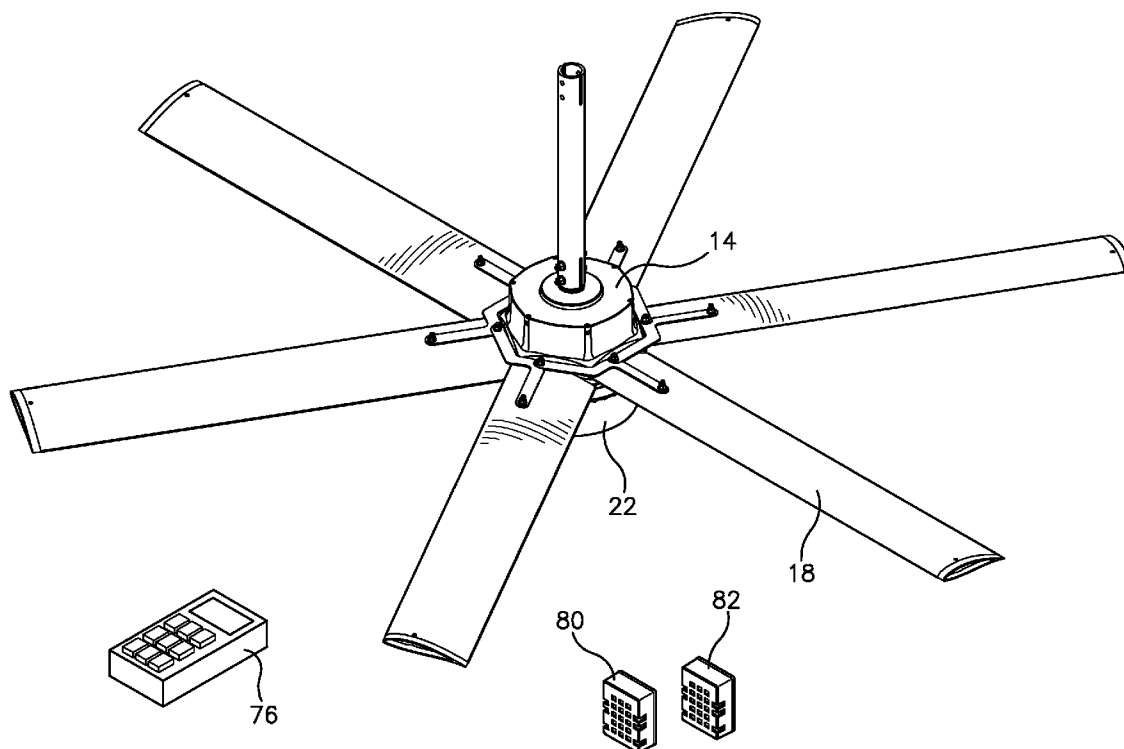
(19) **United States**(12) **Patent Application Publication**
Danielsson(10) **Pub. No.: US 2015/0147188 A1**(43) **Pub. Date: May 28, 2015**(54) **HIGH VOLUME LOW SPEED FAN USING
DIRECT DRIVE TRANSVERSE FLUX
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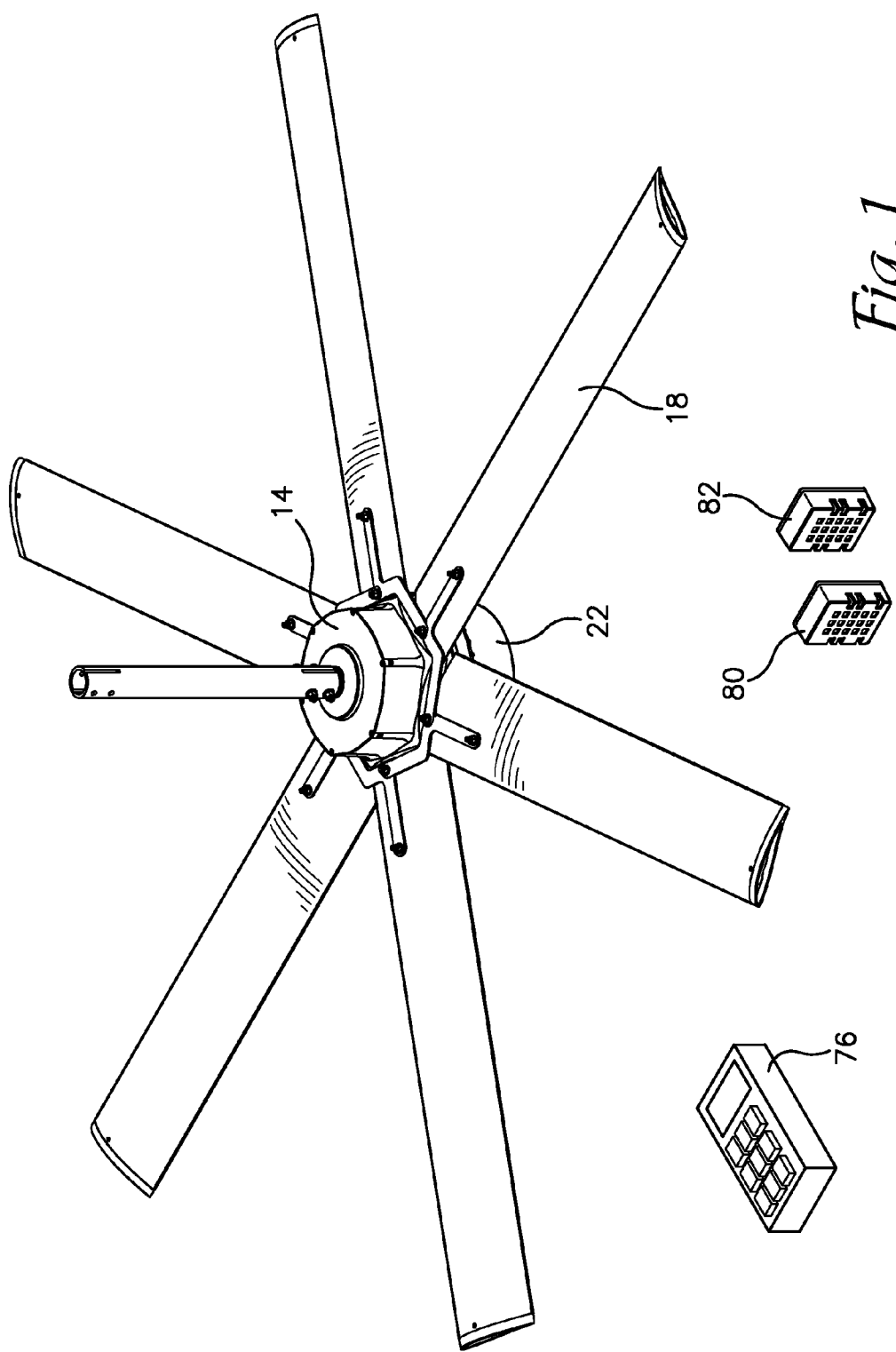
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(57) **ABSTRACT**

Disclosed is a high volume low speed (HVLS) fan that is designed to circulate air in large buildings for cooling, heating, and ventilation. A fan with a diameter between 8 to 24 feet consisting of a plurality of blades, with each in the shape of a tapered airfoil, is driven by a direct drive transverse flux electric motor to produce a very large slowly moving column of air. The HVLS system preferably includes motion and angular shutdown, voltage recognition, blade size recognition and data logging for recording the last 100 or so hours of operation to facilitate warranty applicability and assist in trouble shooting as well as software updates and programming via Bluetooth and internet keypad.





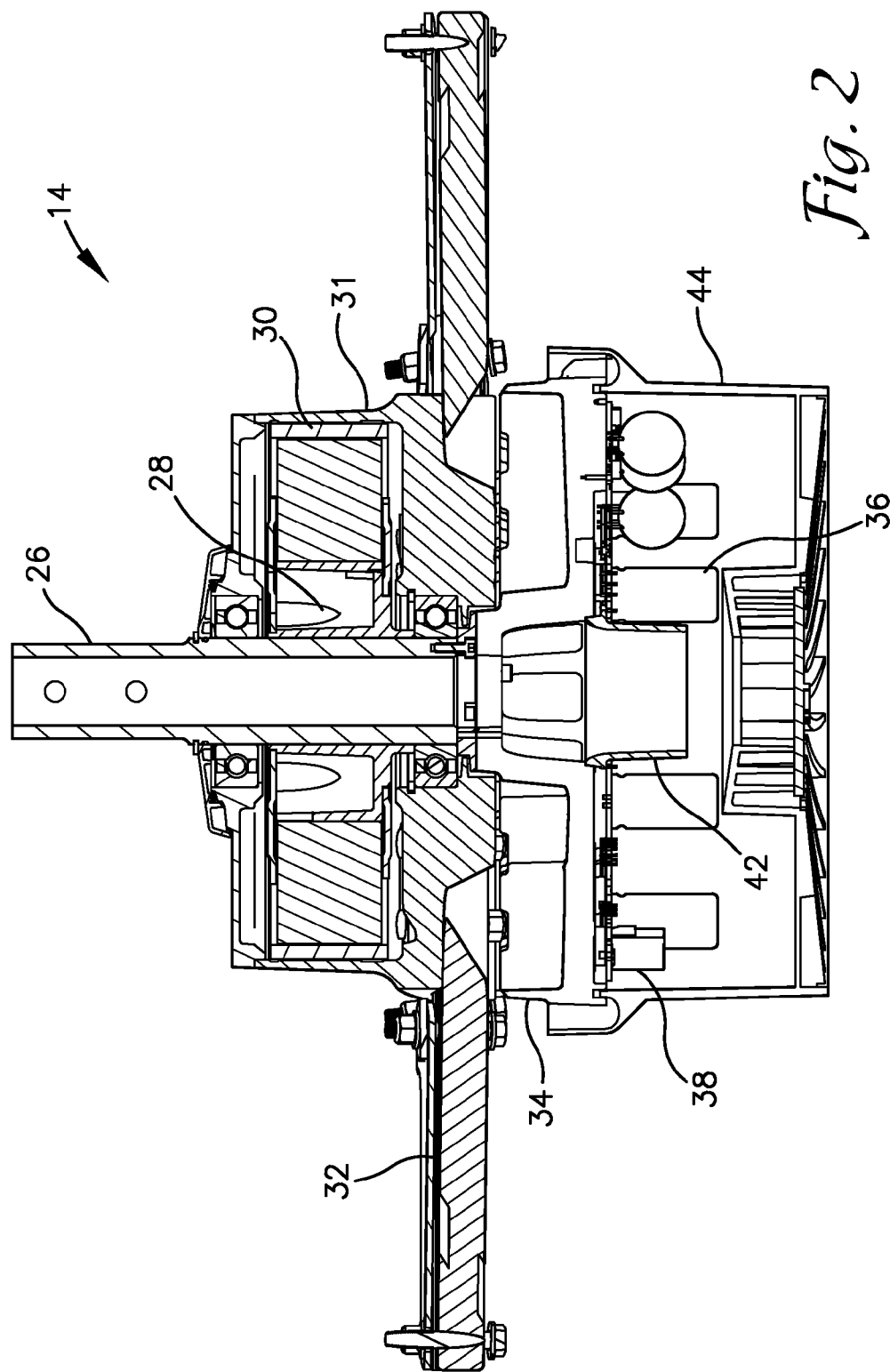
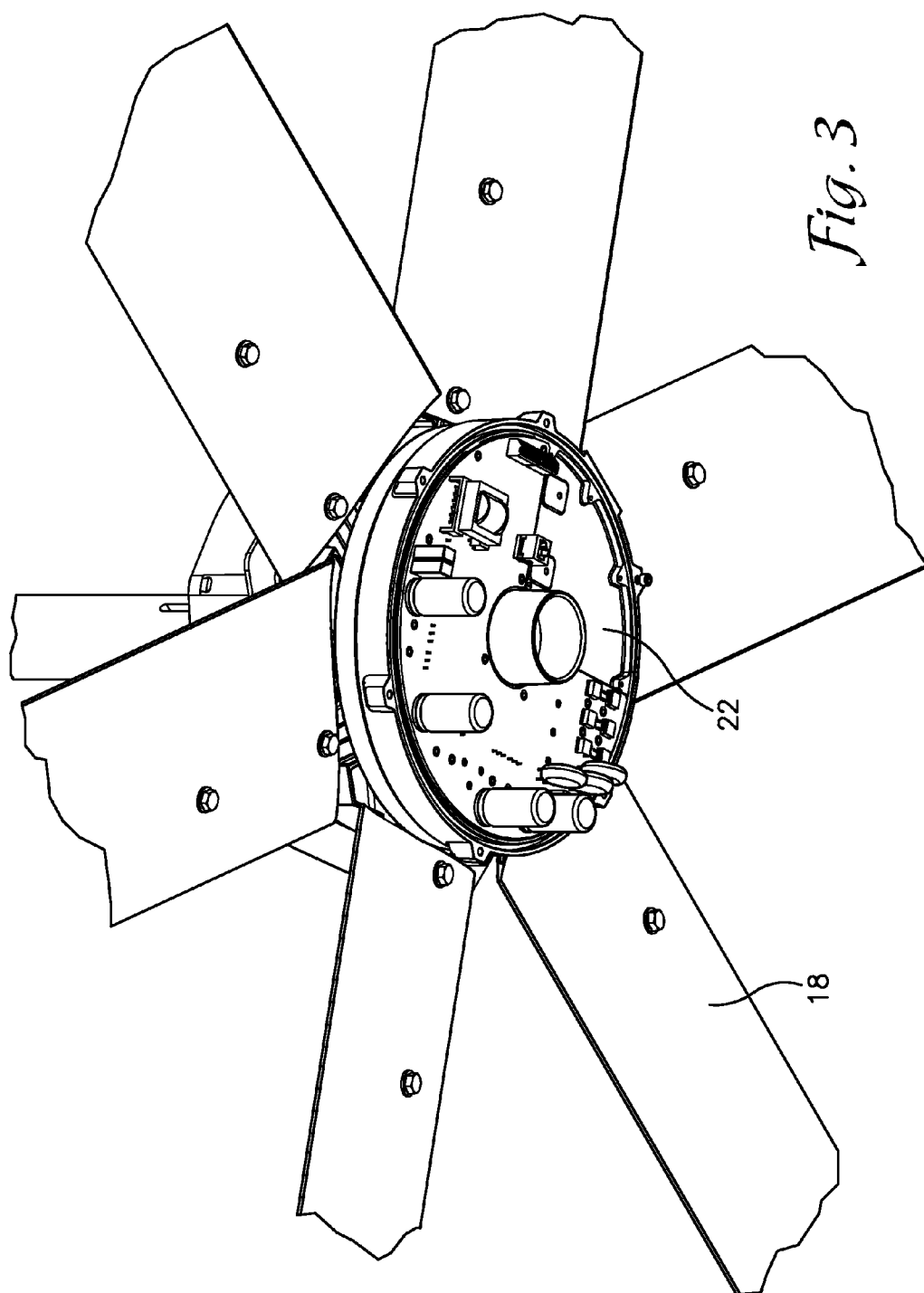


Fig. 2



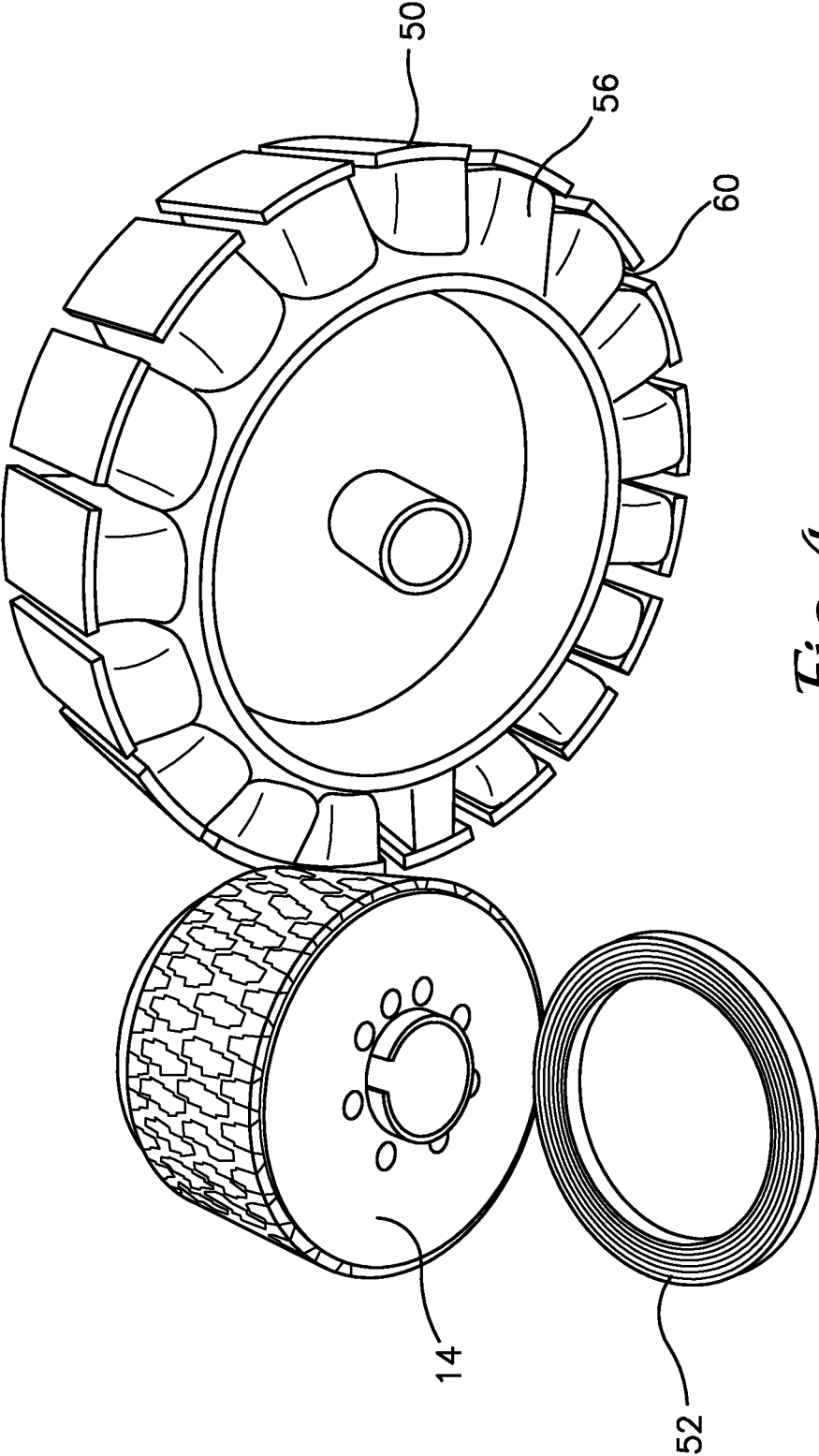


Fig. 4

HIGH VOLUME LOW SPEED FAN USING DIRECT DRIVE TRANSVERSE FLUX MOTOR

RELATED APPLICATION

[0001] This application claims the benefit of priority to U.S. Provisional Application No. 61/908,542 filed on Nov. 25, 2013.

TECHNICAL FIELD

[0002] The present disclosure relates to high volume low speed fans utilizing a direct drive transverse flux motor and control system configured in accordance with principles of the present disclosure.

BACKGROUND

[0003] People who work in large structures such as warehouses and manufacturing plants are routinely exposed to working conditions that range from being uncomfortable to hazardous. On a hot day, the inside air temperature can reach a point where a person is unable to maintain a healthy body temperature. Moreover, many activities that occur in these environments, such as welding or operating internal combustion engines, create airborne contaminants that can be deleterious to those exposed. The effects of airborne contaminants are magnified to an even greater extent if the area is not properly vented.

[0004] The problem of cooling large structures cannot always be solved using conventional air-conditioning methods. In particular, the large volume of air that is enclosed within a large structure would require powerful air conditioning devices to be effective. If such devices were used, the operating costs would be substantial. The cost of operating large air conditioning devices would be even greater if large doors were routinely left in an open state or if ventilation of outside air was required.

[0005] In general, fans are commonly used to provide some degree of cooling when air conditioning is not feasible. A typical fan consists of a plurality of pitched blades radially positioned on a rotatable hub. The tip-to-tip diameter of such fans typically range from 3 feet up to 5 feet.

[0006] When a typical fan rotates under the influence of a motor at higher rotational speeds, a pressure differential is created between the air near the fan blades and the surrounding air, causing a generally conical flow of air that is directed along the fan's axis of rotation. The conical shape combined with drag forces acting at the boundary of the moving mass of air cause the airflow pattern to flare out in a diffusive manner at downstream locations. As a consequence, the ability of these types of fans to provide effective and efficient cooling can be limited for individuals located at a distance from the fan.

[0007] In particular, the effectiveness of a fan is based on the principle of evaporation. When the temperature of a human body increases beyond a threshold level, the body responds by perspiring. Through the process of evaporation, the more energetic molecules comprising the perspiration are released into the surrounding air, thus resulting in an overall decrease in the thermal energy of the exterior of the individual's body. The decrease in thermal energy due to evaporation serves to offset positive sources of thermal energy in the individual's body including metabolic activity and heat conduction with surrounding high temperature air.

[0008] The rate of evaporative heat loss is highly dependent on the relative humidity of the surrounding air. If the surrounding air is motionless, then a layer of saturated air usually forms near the surface of the individual's skin which dramatically decreases the rate of evaporative heat loss as it prevents the evaporation from the individual's body. At this point, perspiration builds up causing the body to break out into a sweat. The lack of an effective heat loss mechanism results in the body temperature increasing beyond a desired level.

[0009] The airflow created by a fan helps to break up the saturated air near the surface of a person's skin and replace it with unsaturated air. This effectively allows the process of evaporation to continue for extended periods of time. The desired result is that the body temperature remains at a comfortable level. In large buildings, the conventional strategy for cooling individuals has been to employ many commonly available small diameter indoor fans. Small diameter fans have been favored over large diameter fans primarily because of physical constraints. In particular, large diameter fans require specially constructed high-strength light-weight blades that can withstand large stresses caused by significant gravitational moments that increase with an increasing blade length to width aspect ratio. In addition, the fact that the rotational inertia of the fan increases with the square of the diameter requires the use of high torque producing gear reduction mechanisms. Moreover, drive-train components are highly susceptible to mechanical failure due to the very large torques produced by conventional electric motors during their startup phase.

[0010] A drawback of using a conventional small diameter fan to create a continuous flow of air is that the resulting airflow dramatically decreases at downstream locations. This is due to the conical nature of the airflow combined with the relatively small mass of air that is contained in the airflow in comparison to resistive drag forces acting at the edge of the cone. To achieve a sufficient airflow in a large non-insulated building, a very large number of small diameter fans would be required. However, the large amount of electrical power required by the simultaneous use of these devices in great numbers negates their advantage as an inexpensive cooling system. Moreover, the use of many fans in an enclosed space can also result in increased air turbulence that can actually decrease the air flow in the building thereby decreasing the cooling effect of the fan.

[0011] To achieve a sufficient airflow in large buildings without relying on an impractically large number of small diameter fans, a small number of small diameter fans are typically operated at very high speeds. However, although these types of fans are capable of displacing a large amount of air in a relatively small amount of time, they do so in an undesirable manner. In particular, a small high speed fan operates by moving a relatively small amount of air at a relatively high speed. Consequently, the speed of the airflow adjacent the fan and the level of noise produced are both very high. Furthermore, lighter weight objects, such as papers, may get displaced by the high speed air flow, thus causing a major disruption to the work environment.

[0012] Another problem with high speed fans is that they are inefficient at entraining a large enclosed volume of air in a steady continuous airflow pattern. In particular, assuming a best case scenario of laminar airflow, the power consumption of a fan is proportional to the cube of the airspeed produced by the fan. Consequently, an electrically driven high speed fan having a correspondingly high speed airflow consumes elec-

trical power at a relatively large rate. Furthermore, the effects of turbulence, which become more pronounced as the speed of the airflow increases, cause the translational kinetic energy associated with the airflow of a high speed fan to be dissipated within a relatively small volume of air. Consequently, even though a relatively large amount of electrical power is consumed by the high speed fan, negligible airflows are produced at locations that are distant from the fan.

[0013] To overcome insufficient airflow problems, larger numbers of high speed fans are sometimes used. However, this solution increases the ambient noise and operating costs even further. In addition, regions of fast moving air are expanded, thus increasing the risk of injury to exposed individuals. In particular, if the air is moving fast enough, foreign objects can become airborne, thus causing a hazardous situation. Papers and other light objects can also be greatly affected. Moreover, if the air temperature is above the skin temperature of an individual, then air moving faster than what is needed to break up the boundary layer actually reduces the cooling effect due to the increased rate of heat flow from the higher temperature air to the lower temperature skin of the individual.

[0014] In addition to cooling, fans are also relied upon in ventilation systems that serve to remove airborne contaminants such as exhaust or smoke. Typical ventilation systems consist of a set of high speed fans located at the perimeter of the structure. However, the previously mentioned problems of high speed fans apply to high speed ventilation fans. The most serious problem is that some areas inside the structure are not properly ventilated.

[0015] To improve ventilation, high speed indoor fans are sometimes used to distribute contaminants throughout the entire volume of a structure. However, the same limitations of high speed indoor fan systems described earlier apply to the problem of ventilation. In particular, high speed indoor fans are loud, inefficient, provide an insufficient airflow to some regions, and provide an undesirably large airflow to others.

[0016] From the foregoing reasons, it will be appreciated that there is a need for a cost efficient cooling device that can be effectively operated in large buildings. Furthermore, there is a need for such a device that is very efficient and does not disrupt the work environment with excessive noise or high speed airflows. Furthermore, there is a need for such a device that will dilute concentrated pockets of contaminated air contained within the structure more uniformly, thus providing optimal ventilation to the structure when used in conjunction with a conventional ventilation system.

[0017] For the foregoing reasons, there is a need for a high volume low speed (HVLS) fan with an efficient electric motor that is capable of operating at various rotational speeds and/or loads, and preferably low rotational speeds. The motor must be capable of being operated within a narrow RPM range and/or load range at a suitable efficiency.

[0018] For the foregoing reasons there is a need for an HVLS fan that avoids being gear driven due to the maintenance and in particular in relation to the lubrication requirements. Gear box seals can develop leaks and should the oil seep out, the gear mechanism can lock up due to lack of lubrication because of the gear metal to metal contact. Gear boxes also generate heat which can be counterproductive in a setting where the objective is to provide cooling.

[0019] For the foregoing reasons, there is a need for an HVLS fan motor capable of being operated efficiently at low rotational speeds with sufficient torque and a minimal need

for periodic maintenance and repairs. HVLS gearboxes are traditionally coupled to an electric motor to achieve a desired output RPM or other output condition. However, gearboxes are often costly, bulky, heavy, and/or impose additional energy losses, for example frictional losses. Such mechanical components can reduce the overall efficiency of the combined system. For example, an electric motor operating at about 85% efficiency coupled to a gearbox operating at about 65% efficiency results in a motor/gearbox system having an overall efficiency of about 55%. Moreover, a gearbox may be larger and/or weigh more or cost more than the conventional electric motor itself. Gearboxes also reduce the overall reliability of the system.

[0020] For the foregoing reasons, there is a need for an HVLS fan with an electric motor that does not contain large volumes of copper wire or other coil material. Due to the length of the coil windings, resistive effects in the coil lead to coil losses. Such losses convert a portion of electrical energy into heat, reducing efficiency and potentially leading to thermal damage to and/or functional destruction of the motor and raising the ambient temperature within the structure being cooled.

[0021] For the foregoing reasons, there is a need for an HVLS fan to include a sensor that comprises an accelerometer, wherein the accelerometer is configured to communicate a signal to the control system in response to detecting an impact against the fan system or an imbalance of the fan system.

[0022] For the foregoing reasons, there is a need for a method for controlling the operation of the HVLS from a remote location using a communication modality such as infrared (IR), Bluetooth (BT) or Wi-Fi. A communication link is established with the HVLS and instructions may then be transmitted to the control system via the communication modality.

SUMMARY

[0023] This disclosure relates to a HVLS fan that is powered by a transverse flux motor. An exemplary transverse flux motor may comprise a rotor, a stator, and a coil. Moreover, a transverse flux machine may be configured with any suitable components, structures, and/or elements in order to provide desired electrical, magnetic, and/or physical properties.

[0024] In an exemplary embodiment, an HVLS fan is driven by a transverse flux motor wherein the HVLS fan does not utilize a gearbox, and/or similar mechanical component (s). In this exemplary embodiment, the HVLS fan is significantly lighter than a similarly sized HVLS fan driven by a traditional electric drive motor utilizing a gear box. The reduced weight will facilitate an increase in motor efficiency, reduced noise and few components requiring maintenance.

[0025] In an exemplary embodiment, an HVLS fan driven by a transverse flux motor will have a broad RPM range of suitable efficiency and/or suitable output torque and may desirably be utilized in a variety of HVLS fan applications where a direct-drive configuration is advantageous. For example, a transverse flux motor having an efficiency greater than 80% over an RPM range from only a few RPMs to about 300 RPMs is highly desirable in nearly all HVLS settings.

[0026] Another drawback to existing HVLS fans is the level of noise generated by existing drive systems. Whether driven by a traditional magnetic motor or by a transverse flux motor existing drive systems currently include a gear box in order to achieve sufficient torque to start rotation of the fan blades and

to drive them at the higher rpm range allowing the fan to overcome resistance generated by the blades moving through the air.

[0027] In another exemplary embodiment, an HVLS fan will utilize an accelerometer. In the event of either an impact or a significant imbalance condition, the accelerometer may detect a lateral acceleration resulting from the impact or imbalance, and may send a corresponding signal to an onboard control system. The accelerometer sensor and control circuitry is preferably integrated into the control system.

[0028] In another exemplary embodiment, an HVLS fan will incorporate a communication modality such as infrared (IR), Bluetooth (BT) or Wi-Fi. A communication link is established with the HVLS and instructions may then be transmitted to the control system via the communication modality.

[0029] Various objects, features, aspects and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawings in which like numerals represent like components. The contents of this summary section are provided only as a simplified introduction to the disclosure, and are not intended to be used to limit the scope of the appended claims.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. 1 is a perspective view of an embodiment of a high volume low speed (HVLS) fan system;

[0032] FIG. 2 is a cutaway view of an embodiment of a transverse flux motor;

[0033] FIG. 3 is a perspective view of an embodiment of a HVLS fan detailing the controller components; and

[0034] FIG. 4 is a perspective view of a transverse flux motor stator and coil as well as a traditional stator.

DETAILED DESCRIPTION

[0035] The following description is of various exemplary embodiments only, and is not intended to limit the scope, applicability or configuration of the present disclosure in any way. Rather, the following description is intended to provide a convenient illustration for implementing various embodiments including the best mode. As will become apparent, various changes may be made in the function and arrangement of the elements described in these embodiments without departing from the scope of the appended claims.

[0036] As seen in FIG. 1, the disclosed technology is directed to a high volume low speed fan (HVLS) 10 comprised of a transverse flux motor 14 such as that manufactured by Electric Torque Machines of Flagstaff, Ariz., fan blades 18 mounted to struts 16 and a controller 22. Trust Automation, Inc. of San Luis Obispo, Calif. manufactures an exemplary fan controller such as their fan controller with model number C-2411-CG01. The disclosed technology does not require a gear box to reduce the rotational speed of the electric motor 14 or increase its output torque. FIG. 2 reveals an embodiment of a transverse flux motor 14 that details the bearings 24 surrounding the drive shaft 26 as well as the stator 28 and rotor 30 surrounded by the motor housing 31. FIG. 2 further reveals the struts 16 extending outwardly for attachment to the fan blades 18. The motor embodiment depicted in FIG. 2

reveals a heat sink 34 as well as the components 36, including a drive 38 of a controller 40 and a drive boot 42. The controller 22 is shielded with a bottom cover 44 to protect the individual components 36 and drive 38 against damage and the collection of dust on the controller 22 circuit board 38.

[0037] FIG. 3 reveals an embodiment of the fan controller 22 with the bottom cover 44 removed. As best seen in FIG. 4, the transverse flux motor 14 is distinctly different from conventional motors 50 in that transverse flux motor 14 uses simple toroidal coils 52 with the stator 54 'wrapped' around the coil 52 while conventional motors 50 usually require copper coils 56 that encircle individual stator teeth 60. Conventional windings suffer from poor slot fill and end turn inefficiencies that become worse as pole count increases. By using a single toroidal coil per phase, transverse flux motors enable high pole counts with very low winding resistance. This results in motors that produce unusually high continuous torque per size and weight, while matching or exceeding industry leading peak torque output.

[0038] The use of a transverse flux motor allows for longer duty cycles, increased efficiency, excellent thermal properties, and, where current HVLS systems require larger conventional motors, increased cost savings resulting from the ability to provide matching torque requirements in a much smaller motor mass. In an exemplary embodiment, the disclosed drive motor technology provides torque in the 13 to 170 Newton-meter range with rotational speeds in the range of from 50-220 rpm and is capable of operating at temperatures approaching 60 degrees centigrade.

[0039] In another exemplary embodiment, centrifugal overheat protection provides supplemental cooling. The advanced motor control technology provides added cooling protection as the programmed controller 22 may be set to slow the fan rotational speed if the ambient temperature exceeds the rated temperature of the motor for a period of time until the ambient temperature is reduced by the air the fan moves. In another exemplary embodiment, an impact or a significant imbalance condition in the HVLS may be detected by a lateral acceleration resulting from the impact or imbalance. It will be appreciated that there are a variety of ways in which a signal from an accelerometer may be used to influence the operation of a fan system. For instance, the signal from the accelerometer may initiate a controlled deceleration sequence to bring the fan system to a gradual and controlled stop. Alternatively, the signal from the accelerometer may simply cause the power supply to be disconnected from the motor.

[0040] Furthermore, to the extent that the sensitivity of the accelerometer is adjustable, the fan system may be configured whereby different conditions sensed by the accelerometer may produce different results. Furthermore, any suitable alternative to an accelerometer may be used, to detect any of the above noted conditions or to detect other conditions.

[0041] Another embodiment of the fan may also include a motion and angular shutdown feature. This safety feature is added in the event an accident occurs or if the fan is operated in an unsuitable application such as when cross winds are present. This feature eliminates or greatly reduces the need to rely upon guy wires for vertical and safe operations. In addition, voltage recognition enables stocking of one unit for many different users. This feature enables the use of a broad range of incoming voltages, such as 110V, 240V to include single or three phase installations. These voltage variations

are all recognized and the fan operation is fully functional without changing parts or software programs.

[0042] Another feature of the preferred technology is blade size recognition which enables stocking by vendors of one unit for many fan sizes. This technology enables the same power unit (motor and drive) to operate various blade lengths without software changes. The fan blades rotational speed is adjusted by how much current is sent to the motor via the controller 22, more current equals more torque which relates to the resulting RPM that overcomes the resistive torque created by the air friction drag on the blades 18. Blade diameter verification works by applying a certain torque to the blades, the torque that is applied will correspond with a certain rotational speed for each blade diameter and the controller 22 will read the rotational speed and confirm that it is within tolerance for the selected blade 18 diameter profile. If a shorter blade is mounted to the fan, the applied torque would result in a rotational speed that is faster than what is allowed by the controller 22, resulting in a fault code that is displayed on the wall mounted user input panel 76. Likewise, if blades that are too long are mounted to the fan, the controller would relay a code showing that the blades are not spinning fast enough to meet the acceptable rotational speed limits set by the controller 22.

[0043] The preferred embodiment utilizes a blade profile/program that is selected through the remote control panel/user input panel 76 such as shown in FIG. 1. The auto blade detect feature operates by applying the torque required to run the smallest blade diameter at full speed. Once blades are turning at a constant rotational speed this speed is measured and verified against a look up table. Each blade length will turn at different rotational speed with this applied torque and the controller 22 will set the appropriate blade profile. Once the blade length is set, the blade diameter verification feature will be running in the background to make sure the blade rotational speeds are always within tolerance.

[0044] Another preferred feature is the data logger recording of approximately the last 100 hours of operation of the fan to address warranty issues and to provide trouble shooting assistance. The controller also maintains a count of the hours of operation up to 50,000 hours. The vendor can then use the hour count feature supplied with the controller to assess how many hours the fan has been operating. This feature is very useful for warranty purposes, for example at 30,000 hours of operation, the fan warranty expires. Each vendor can choose the number of hours of operation at which to terminate their warranty. In addition, software updates and programming of the controller 22 are accomplished through Bluetooth, the internet or a Modbus keypad. Sensor inputs to include humidity 80 and temperature 82 sensors will allow the fan to react automatically to maximize human comfort by automatically switching from downward airflow (cooling) to upward airflow (heating) based on the thermal conditions of the building. Lastly, the fan controller and drive motor can undergo troubleshooting via Bluetooth and an internet Modbus keypad/device. This feature greatly reduces the need for a technician to be lifted to the fan motor and controller to access the fan at the ceiling level for initial trouble shooting.

[0045] The preferred embodiment of the disclosed technology can also be integrated with a building management system wherein the building management system integrates the fan with lighting, heating and cooling systems, doors and other components connected to the system. For example, should the building lighting system generate excess heat cre-

ating a comfort problem for the occupants, distributed sensors will sense the environmental change and relay information to the controller to increase the fan speed and increase air circulation. Likewise, should a door be left open and the interior temperatures begin to drop the building heating system working in concert with the fans will operate to maintain the desired temperature in the structure.

[0046] Having shown and described various embodiments of the present invention, further adaptations of the methods and systems described herein may be accomplished by appropriate modifications by one of ordinary skill in the art without departing from the scope of the present invention. Several of such potential modifications have been mentioned, and others will be apparent to those skilled in the art. For instance, the examples, embodiments, geometries, materials, dimensions, ratios, steps, and the like discussed above are illustrative and are not required. Accordingly, the scope of the present invention should be considered in terms of the following claims and is understood not to be limited to the details of structure and operation shown and described in the specification and drawings.

We claim:

1. A fan for use in a building comprising:
 - a transverse flux motor operably coupled to a plurality of struts;
 - a plurality of fan blades mounted to and extending outwardly from the plurality of struts;
 - a controller in operable communication with a user interface and the transverse flux motor.
2. The fan of claim 1, wherein the controller is configured to operate the transverse flux motor to provide cooling in the building in response to human input to the user interface.
3. The fan of claim 1, wherein the controller is configured to receive a humidity input from a humidity sensor.
4. The fan of claim 1, wherein the controller is configured to receive a temperature input from a temperature sensor.
5. The fan of claim 1, wherein the controller is configured to provide automatic resumption of blade rotation when a fault code is corrected.
6. The fan of claim 1, wherein the controller is configured to integrate with a building management system.
7. The fan of claim 1, wherein the controller is configured to sense the rotational speed of the fan and confirm that the speed is within the tolerance for the selected blade diameter profile.
8. A fan for use in a building comprising:
 - a transverse flux motor directly coupled to a plurality of struts;
 - a plurality of fan blades mounted to and extending outwardly from the plurality of struts; and
 - a controller in operable communication with a user interface and the transverse flux motor, the controller configured to (i) operate the transverse flux motor to provide air flow in the building in response to human input through the user interface, (ii) operate the transverse flux motor to provide a high volume of low speed air in response to an input from a humidity sensor, (iii) operate the transverse flux motor to provide a high volume of low speed air in response to a temperature input from a temperature sensor, (iv) provide automatic resumption of blade rotation when a fault code is corrected, (v) receive input from a building management system, and (vi) operate the transverse flux motor with a wide range of voltage magnitude.

9. The fan of claim 8, wherein the user interface comprises a software option for selecting the speed of rotation of the transverse flux motor.

10. The fan of claim 8, further comprising a memory module in communication with the controller, the memory module for storing user preferred operating parameters.

11. The fan of claim 8, wherein the controller monitors rotational speed, load and motion variations.

12. The fan of claim 8, wherein the controller recognizes blade size.

13. The fan of claim 8, wherein controller software updates may be uploaded through a Modbus device or Bluetooth.

14. The fan of claim 8, wherein troubleshooting of the controller and transverse flux motor may be performed through a Modbus device.

15. The fan of claim 8, wherein the building management system further integrates the fan with lighting, heating and cooling systems, doors and other features connected to the system.

16. The fan of claim 8, wherein an hour meter is in operable communication with the controller for monitoring the duration of operation of the transverse flux motor.

17. The fan of claim 8, wherein the wide range of voltage magnitude is from 110 to 636 volts.

18. The fan of claim 17, wherein single phase or three phase voltages are recognized by the controller.

19. The fan of claim 8, wherein the controller monitors hours of operation for warranty purposes.

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