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OH (US)(51) **Int. Cl.**
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HOUSTON, TX 77002(57) **ABSTRACT**

A centralized cooling system can selectively deliver individualized cooling to individual electrical load units. The system can provide direct cooling from a manifold of cooling outlets in a controlled manner based on the sensed electrical loads of particular load units. A branch monitoring system monitors the load on electrical feeds that are coupled to electrical load units. A controller is coupled to the branch monitoring system and provides output to control a cooling unit. At least one control valve is further coupled to the controller downstream of the cooling unit generally at each cooling outlet to control an amount of cooling fluid, such as air or liquid, directed to one or more of the units. If a load changes for a given unit, the controller can actuate a cooling valve coupled to a corresponding cooling outlet and alter the amount of cooling fluid flowing into or around the unit(s).

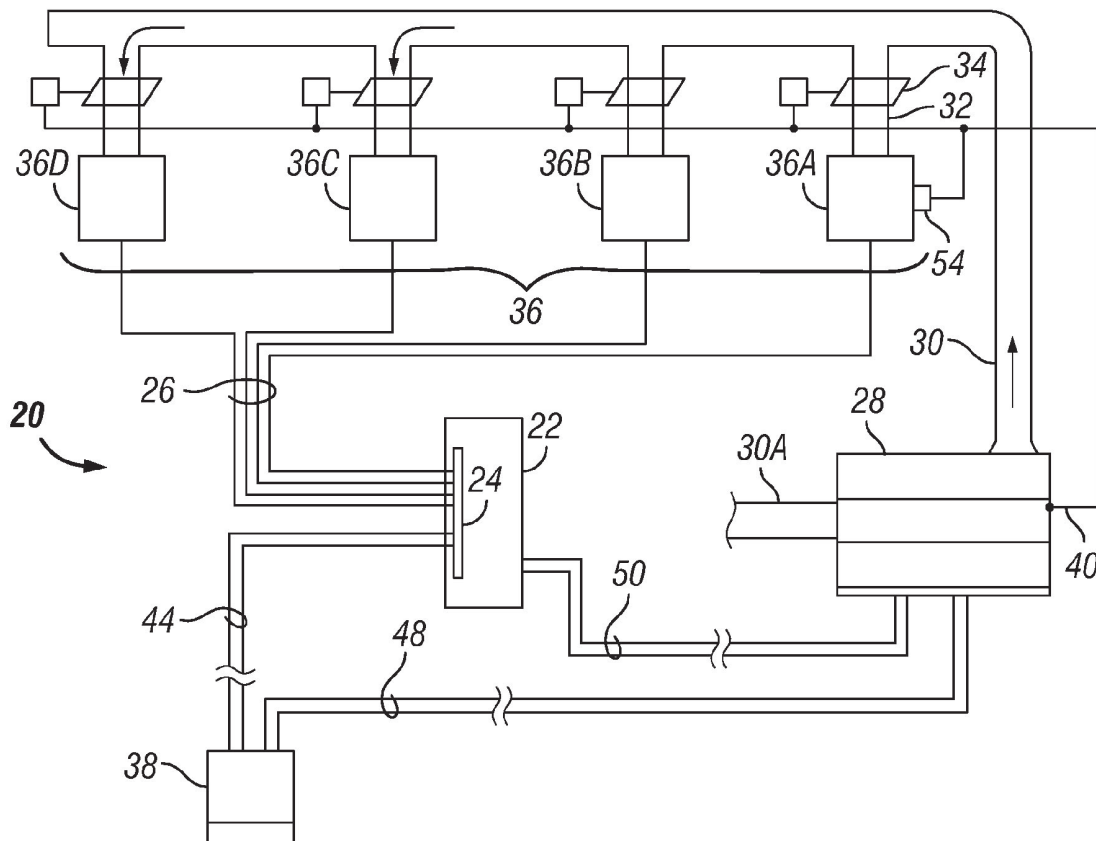
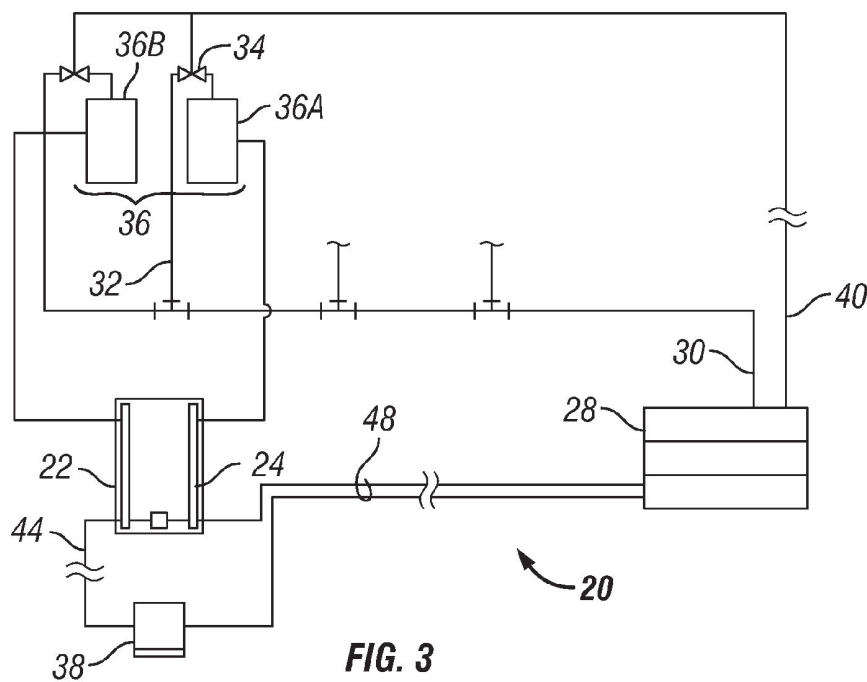
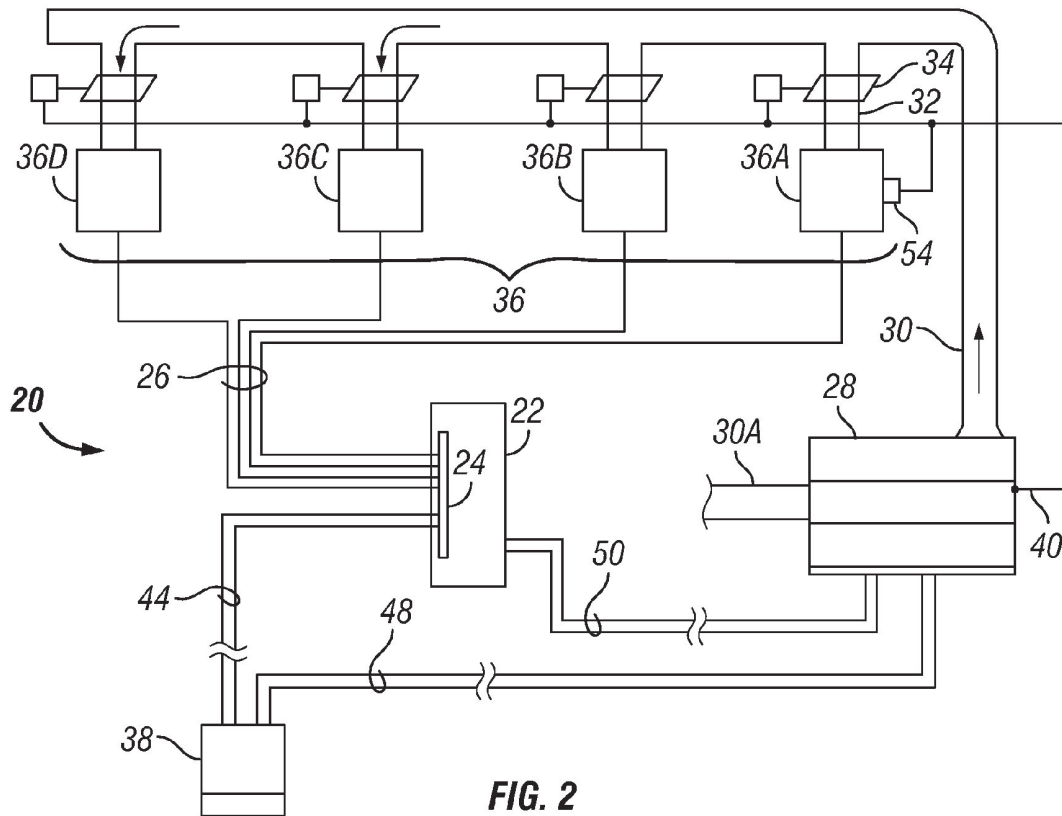
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Columbus, OH (US)(21) **Appl. No.:** **11/670,208**(22) **Filed:** **Feb. 1, 2007****Related U.S. Application Data**(60) Provisional application No. 60/862,538, filed on Oct.
23, 2006.



FIG. 1
(Prior Art)



THERMAL LOAD LOCATOR**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Appl. No. 60/862,538, filed Oct. 23, 2006, and is incorporated herein by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

REFERENCE TO APPENDIX

[0003] Not applicable.

BACKGROUND OF THE INVENTION

[0004] 1. Field of the Invention.

[0005] The present invention relates generally to electronic equipment cabinets and housings, and, more particularly to electronic equipment cabinets having cooling systems.

[0006] 2. Description of the Related Art.

[0007] With the expansion of telecommunication and computer technology, increasing amounts of electronic equipment are required at businesses and other facilities. Large amounts of electronic equipment are often stored in a room devoted to that purpose. As shown in FIG. 1, the equipment is generally organized in a cabinet 2 of standard dimensions with multiple horizontal trays 4 to support multiple rows of equipment. The cabinet 2 generally includes sides 6, back 8, top 10, bottom 12, and a door 14 to gain access to the equipment therein. Power rails, uninterruptible power supplies, and other features can be included. This equipment generates heat, which must be removed from the room in order to maintain stable conditions in the rooms. Because advances in technology have lead to an increased density of the amount of electronic equipment that can be provided in a set amount of space, it has become increasingly difficult to remove this heat by means of the conventional room air conditioning sized according to traditional practices.

[0008] General purpose cooling systems for rooms and open spaces now are either oversized and inefficient to handle the additional cooling requirements or inadequate for single racks of critical electronic equipment that may incur particular heavy loads. Therefore, it is often necessary to install localized cooling for the cabinets that house this electronic equipment. Some existing commercial suppliers have provided a closed loop refrigerated cooling system coupled to the cabinets. The refrigeration system typically includes a compressor for compressing refrigerant in the system to an elevated pressure, a condenser to cool the refrigerant that is heated by the act of compression, an expansion device that thermodynamically cools the refrigerant, an evaporator that is cooled by the cooled refrigerant flowing therethrough, a fan to move air across the evaporator's surfaces to cool the air whereby the refrigerant in turn absorbs heat from the warmer air, various refrigeration lines for carrying the refrigerant between the components, and a system controller, such as a thermostat. These systems are typically mounted in the bottom or on top of the cabinet. A typical cabinet is about 24" wide and 78" to 84" high. The cooling module can consume about 12"-15" in the bottom of

the cabinet or add such amount to the overall height if mounted on top of the cabinet. While having individual cooling systems per cabinet has been well received, it raises the costs per cabinet and adds complexity to the system.

[0009] Another challenge with existing electronic equipment cabinets with built-in cooling coils and fans is that they typically do not respond quickly to large, instantaneous changes in heat load. The cooling system senses the heat after the heat has been generated and then attempts to compensate by extra cooling to lower the temperature back down to an intended set point. The cooling system is therefore responsive to thermal heat after it has been produced. The result can be a wide fluctuation of temperatures in the cabinet, as the cooling system's control system responds to the load change.

[0010] Therefore, there remains a need for an improved cooling system for electronic equipment cabinets.

BRIEF SUMMARY OF THE INVENTION

[0011] The present invention provides a centralized cooling system can selectively deliver individualized cooling to individual electrical load units, such as individual cabinets, racks of such cabinets, or other cooled units. The system can provide direct cooling from a manifold of cooling outlets in a controlled manner based on the sensed electrical load of a particular cabinet, rack, or other unit. The system generally includes a branch monitoring system coupled to each branch circuit that is monitored from which electrical feeds are coupled to a plurality of electrical load units, and a controller coupled to the branch monitoring system. The controller provides output to control a cooling unit, such as an air conditioner. At least one control valve is further coupled to the controller downstream of the cooling unit generally at each cooling outlet to control an amount of cooling fluid, such as air or liquid, directed to one or more of the electrical load units. Data can be communicated between the branch monitoring system, the controller, the cooling unit, or a combination thereof. If a load and/or a change in load is sensed for a given electrical load unit(s), the controller can actuate a cooling valve coupled to a corresponding cooling outlet and alter the amount of cooling fluid flowing into or around the electrical load unit(s). Further, one or more thermal sensors can be mounted at the load unit to provide feedback from the unit on cooling conditions, so that the controller can make adjustments as necessary.

[0012] The disclosure provides a system to cool a plurality of electrical load units with a central cooling unit, comprising: at least two electrical load sensors coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors, the electrical load sensors being adapted to sense electrical loads on the electrical load units; a controller coupled to the electrical load sensors and adapted to receive data from the load sensors; a central flow conduit coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets and the at least two cooling outlets being coupled to the at least two electrical load units, each of the at least two electrical load units being coupled to at least one of the cooling outlets; and at least two control valves coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves, and the controller being adapted to control the control valves.

flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.

[0013] The disclosure also provides a method of cooling a plurality of electrical load units with a central cooling unit, comprising: delivering electrical current to at least two of the electrical load units; sensing electrical loads on the at least two electrical load units; flowing a cooling fluid through a central flow conduit coupled to the central cooling unit into at least two cooling outlets coupled between the central flow conduit and the at least two electrical load units; and controlling the flow of the cooling fluid proportionately from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0014] A more particular description, briefly summarized above, may be had by reference to the embodiments illustrated in the appended drawings, forming part of the present specification and described herein. It is to be noted, however, that the appended drawings illustrate only some embodiments described herein and are therefore not to be considered limiting of the disclosure's scope, in that there can be other equally effective embodiments.

[0015] FIG. 1 illustrates in perspective view an existing stack of cabinets to support electronic equipment.

[0016] FIG. 2 illustrates a schematic diagram of at least one embodiment of a central cooling system controlled for individual load units, such as cabinets.

[0017] FIG. 3 illustrates a schematic diagram of at least one embodiment of a central cooling system controlled for individual load units, such as racks within cabinets.

DETAILED DESCRIPTION

[0018] The Figures described above and the written description of specific structures and processes below are not presented to limit the scope of what Applicants have invented or the scope of protection for those inventions. Rather, the Figures and written description are provided to teach any person skilled in the art to make and use the inventions for which patent protection is sought. Those skilled in the art will appreciate that not all features of a commercial implementation of the inventions are described or shown for the sake of clarity and understanding. Persons of skill in this art also appreciate that the development of an actual commercial embodiment incorporating aspects of the present inventions will require numerous implementation-specific decisions to achieve the developer's ultimate goal for the commercial embodiment. Such implementation-specific decisions may include, and likely are not limited to, compliance with system-related, business-related, government-related and other constraints, which may vary by specific implementation, location and from time to time. While a developer's efforts might be complex and time-consuming in an absolute sense, such efforts would be, nevertheless, a routine undertaking for those of skill in this art having benefit of this disclosure. The inventions disclosed and taught herein are susceptible to numerous and various modifications and alternative forms. Lastly, the use of a singular term is not intended as limiting of the number of items. Also, the use of relational terms, such as, but not

limited to, "top," "bottom," "left," "right," "upper," "lower," "down," "up," "side," and the like are used in the written description for clarity in specific reference to the Figures and are not intended to limit the scope of the invention or the appended claims. The term "coupled," "coupling," "coupler," and like terms are used broadly herein and can include any method or device for securing, binding, bonding, fastening, attaching, joining, inserting therein, forming thereon or therein, communicating, or otherwise associating, for example, mechanically, magnetically, electrically, chemically, directly or indirectly with intermediate elements, one or more pieces of members together and can further include without limitation integrally forming one functional member with another in a unity fashion. The coupling can occur in any direction, including rotationally.

[0019] FIG. 2 illustrates a schematic diagram of at least one embodiment of a central cooling system controlled for individual load units, such as cabinets. The system 20 generally includes at least one sensor coupled to at least one electrical load unit of a plurality of electrical load units, a controller coupled to the sensor, a central flow conduit coupled to a central cooling unit, at least one cooling outlet coupled between the central flow conduit and the electrical load unit, and a control valve coupled to the cooling outlet and the controller. The sensor is adapted to sense an electrical load, such as current, on the unit or units to which it is coupled and provide data to the controller for processing and providing instructions to the control valve and/or cooling unit. These elements will be described in more detail below.

[0020] Thus, at least in some embodiments, the electrical load unit in its cooling demands are anticipated even prior to the actual increase in temperature caused from the increased load. Similarly, when the electrical load unit decreases its need for energy, the change in electrical load is sensed, communicated to the controller and the amount of cooling is adjusted. The early sensing of the electrical load allows the controller to control the anticipated cooling needs based on the electrical load among a distributed network of cooled load units. This proactive control can assist in maintaining a cooling environment, for example, before an increased electrical load generates an higher amount of heat that is sensed by a thermal sensor that then requires compensation to restabilize the system affected by the heat. Further, it is believed that the proactive control helps promote more efficient use and sizing of the cooling unit and overall cooling system, because the cooling capacity can be allocated to specific needs on specific electrical load units on a relatively real time basis. The sensing can help avoid the temperature variations and thermal momentum caused by responding the heat after it has been generated by the load, and then sensed by a thermal sensor.

[0021] More particularly, the system 20 generally includes an electrical distribution center 22 having a branch control monitoring system ("BCMS") 24. A plurality of electrical feeds 26 is coupled between the electrical distribution center 22, and particularly the BCMS 24, and a plurality of electrical load units 36A, 36B, 36C, 36D (collectively designated as 36) coupled to a central cooling system. Such electrical load units could include, without limitation, a cabinet having a plurality of racks disposed therein, the racks themselves mounted within the cabinets, specific processors, disk drives, and other electrical components having electrical needs and therefore electrical loads. The

BCMS 24 monitors the individual electrical loads of the branch circuits of, for example, a panelboard through current transformers coupled to the BCMS. The output from the current transformers of the BCMS can be directed to a processor for manipulation and output. A suitable BCMS system is described in U.S. patent application Ser. No. 11/420,784 and U.S. patent application Ser. No. 11/420,786, incorporated herein by reference, and owned by the assignee of this invention, Liebert Corporation, a company of Emerson Electric Co. in the USA. A BCMS can be obtained from the Liebert Corporation, Columbus, Ohio, USA.

[0022] Each of the electrical load units generally require cooling to avoid overheating and possible premature failure caused by the electrical loads. A central cooling unit 28 can be used to provide cooling to the electrical load units. The central cooling unit flows cooling fluid through a central flow conduit 30 which branch to generally a plurality of cooling outlets 32 which are coupled to the electrical load units to be cooled. The cooling medium can be a gas, such as air, or liquid, such as chilled water, and can include air conditioning or water cooled systems. Depending on the cooling needs of the electrical load units, the cooling outlet or outlets can cool individual electrical load units or groups of electrical load units by varying the amount of cooling, such as on a percentage basis, between the distributed electrical load units depending on their individual electrical loads. Generally, a control valve 34, such as an air damper or liquid flow valve, is coupled to each cooling outlet that can control the amount of cooling fluid flowing through the particular cooling outlet to the electrical load unit as a proportion of the overall cooling fluid flowing through the central flow conduit 30 at the particular time. If an increase in an electrical load is sensed for a particular electrical load unit, the controller can direct a greater proportion or amount of cooling flow from the central flow conduit to the particular electrical load unit through the associated cooling outlet.

[0023] Variations are possible. For example, a specific number of electrical load units may have wide variations in electrical loads and one or more other electrical load units may have a relatively constant electrical load. A controllable cooling outlet could be coupled to the varying electrical load units for variable cooling, while a more constant supply of cooling fluid could be provided to the one or more constant electrical load units. In such embodiments, a control valve could optionally be omitted from the constant electrical load units.

[0024] Thus, the control valve 34 can provide a variation in the cooling fluid from the central flow conduit 30 through the cooling outlet 32. The system 20 further includes data and output/input control for the control valve 34. More particularly, the system 20 includes a data communication link 44 from the electrical distribution center 22. A controller 38 can be coupled to the electrical distribution center and particularly the BCMS via electronic communication through the data communication link 44. The data communication link can be hardwired or wireless, such as microwave, infrared, radio waves, and other modes of communication. The controller 38 can generally include an input and output for receiving the data and outputting process data through a data communication link 48 to the cooling unit 28 for control of the cooling unit. In some embodiments, the controller 38 can be physically integrated with the cooling unit 28 so that data flow between the BCMS and the controller could be represented by a data communication

link 50. The controller 38 is also coupled, directly or indirectly, to a control bus 40. The control bus 40 can provide control communication between the controller 38 and the control valve 34. The term "control bus" is used broadly and can include wired or wireless communications. As the load increases or decreases, the controller 38 can direct the control valve 24 to increase or decrease the amount of cooling fluid flowing through a particular cooling outlet 32 with the control valve 34. The controller 38 can also control the cooling unit 28 for more general operation such as cycle times, average temperature in the central flow conduit, and other system wide parameters.

[0025] In some embodiments, the electrical load unit can be further sensed by a temperature sensor or one or more portions of the electrical load unit. The sensor 42 can be coupled to the control bus 40 and provide additional input to the controller 38.

[0026] FIG. 3 illustrates a schematic diagram of an embodiment of a central cooling system for racks of electrical cabinets or devices on the racks, as types of electrical load units. The system 20 can further include providing cooling fluid to individual racks of electrical equipment or specific devices that may be assembled in a cabinet or data center. The electrical distribution center 22 could provide electricity to the electrical load units 36 through the BCMS 24. A data communication link 44 is disposed between the BCMS 24 and the controller 38, and can provide input to the controller on the electrical loads. A cooling unit 28 can provide cooling fluid through a central flow conduit 30 coupled to the electrical load unit 36. A cooling outlet 32 is coupled to the central flow conduit 30 for the particular electrical load unit 36A to be cooled. A control valve 34 is coupled to the cooling outlet 32 for control of fluid there-through between the central flow conduit 30 and the electrical load unit 36A. Other cooling outlets and control valves can likewise be coupled to the other exemplary electrical load unit 36B, and other electrical load units, such as units 36C and 36D, shown in FIG. 2. A control bus 40 is coupled to the control valve 34 for control and operation of the control valve from the controller 38. A data communication link 48 between the controller 38 and the cooling unit 28 and/or control bus 40 provides communication for control.

[0027] The order of steps can occur in a variety of sequences unless otherwise specifically limited. The various steps described herein can be combined with other steps, interlineated with the stated steps, and/or split into multiple steps. Similarly, elements have been described functionally and can be embodied as separate components or can be combined into components having multiple functions.

[0028] The inventions have been described in the context of preferred and other embodiments and not every embodiment of the invention has been described. Obvious modifications and alterations to the described embodiments are available to those of ordinary skill in the art. The disclosed and undisclosed embodiments are not intended to limit or restrict the scope or applicability of the invention conceived of by the Applicants, but rather, in conformity with the patent laws, Applicants intend to fully protect all such modifications and improvements that come within the scope or range of equivalent of the following claims. Further, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", should be understood to imply the inclusion of at least the stated element or step or group of elements or steps, by such variants.

thereof, and not the exclusion of a greater numerical quantity or any other element or step or group of elements or steps or equivalents thereof.

What is claimed is:

1. A system to cool a plurality of electrical load units with a central cooling unit, comprising:

at least two electrical load sensors coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors, the electrical load sensors being adapted to sense electrical loads on the electrical load units;

a controller coupled to the electrical load sensors and adapted to receive data from the load sensors;

a central flow conduit coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets and the at least two cooling outlets being coupled to the at least two electrical load units, each of the at least two electrical load units being coupled to at least one of the cooling outlets; and

at least two control valves coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves, and the controller being adapted to control proportional flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.

2. The system of claim 1, wherein the sensed electrical load is electrical current.

3. The system of claim 1, further comprising a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units.

4. The system of claim 3, further comprising a data communication link coupled between the branch control monitor and the controller.

5. The system of claim 1, wherein the cooling fluid comprises a gas, a liquid, or a combination thereof.

6. The system of claim 1, further comprising a control bus coupled between the controller and the control valves.

7. The system of claim 1, further comprising at least two thermal sensors adapted to sense thermal conditions of the at least two electrical load units and provide thermal data to the controller.

8. The system of claim 1, wherein the electrical load units comprise an electrical cabinet, a rack in the cabinet, or an electrical device.

9. The system of claim 1, wherein the controller is coupled to the cooling unit.

10. A method of cooling a plurality of electrical load units with a central cooling unit, comprising:

delivering electrical current to at least two of the electrical load units;

sensing electrical loads on the at least two electrical load units;

flowing a cooling fluid through a central flow conduit coupled to the central cooling unit into at least two cooling outlets coupled between the central flow conduit and the at least two electrical load units; and

controlling the flow of the cooling fluid proportionately from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.

11. The method of claim 10, wherein sensing the electrical loads comprises sensing electrical currents to the at least two electrical load units.

12. The method of claim 10, further comprising sensing the electrical loads on the at least two electrical load units from a branch monitoring system.

13. The method of claim 10, further comprising sensing thermal conditions of the at least two electrical load units and at least partially controlling the flow of the cooling fluid to the electrical load units based on the sensed thermal conditions.

14. The method of claim 13, further comprising controlling the flow of the cooling fluid based on the sensed electrical loads prior to sensing changes in the thermal conditions.

15. The method of claim 10, wherein sensing the electrical loads comprises sensing an electrical load on an electrical cabinet, a rack of one or more cabinets, an electrical device, or a combination thereof.

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