REFRIGERANT SYSTEM WITH PULSE WIDTH MODULATED COMPONENTS AND VARIABLE SPEED COMPRESSOR

Inventors: Alexander Lifson, Manlius, NY (US); Sriram Srinivasan, Manlius, NY (US)

Correspondence Address: CARLSON, GASKEY & OLDS, P.C. 400 WEST MAPLE ROAD, SUITE 350 BIRMINGHAM, MI 48009 (US)

Publication Classification

- Int. Cl. F25B 41/04 (2006.01)
- F25B 41/00 (2006.01)
- F25B 49/00 (2006.01)

U.S. Cl. ....................................... 62/228.4

ABSTRACT

A variable speed drive is provided for operating a compressor motor in a refrigerant system. When a low load situation has been determined by the refrigerant system controls, the variable speed drive operates the compressor motor at lower speed mode of operation. Further, the operation of the variable speed drive is combined with a pulse width modulation control of different system components. In particular, at least one valve or compressor can be can be rapidly cycled by the control to regulate amount of refrigerant passing through the valve or compressor. Example valves would include a shut-off valve for an economizer cycle, an unloader valve, or a suction modulation valve.
REFRIGERANT SYSTEM WITH PULSE WIDTH MODULATED COMPONENTS AND VARIABLE SPEED COMPRESSOR

BACKGROUND OF THE INVENTION

[0001] This application relates to a control for a refrigerant system having a variable speed compressor, and wherein pulse width modulation technologies are utilized to provide further control over the system.

[0002] Refrigerant systems are utilized in many applications to condition an environment. In particular, air conditioners and heat pumps are employed to cool and/or heat air entering the environment. The cooling or heating load of the environment may vary with ambient conditions, occupancy level, other changes in sensible and latent load demands, and as the temperature and/or humidity set points are adjusted by an occupant of the environment.

[0003] A feature that is known for improving the efficiency of refrigerant systems is the use of a variable speed drive for the compressor motor. Often, the compressor need not be operated at full speed, such as when the cooling load on the refrigerant system is relatively low. Under such circumstances, it might be desirable to reduce the compressor speed, and thus reduce the overall energy consumption of the refrigerant system. Implementation of a variable speed drive is one of the most efficient techniques to enhance system performance and reduce life-cycle cost of the equipment over a wide spectrum of operating environments and potential applications, especially at part-load conditions.

[0004] However, compelling reliability concerns set a lower limit to the desirable compressor speed reduction. As an example, inadequate lubrication of the compressor elements may present a problem at low operating speeds. Further, certain types of compressors require a minimum operating speed to provide radial compliance. As an example, a scroll compressor could have a dramatic loss in performance due to a loss of radial compliance should it operate below a minimum speed.

[0005] Various other features are known for providing variations in system capacity in a manner other than lowering the speed of the compressor. As an example, economizer cycles are known as are unloader cycles. However, even with the provision of these cycles in a system having a variable speed drive for its compressor, it would be desirable to provide even more variability in the system capacity.

[0006] Another approach which has been utilized in the prior art to change the capacity of a refrigerant system is the use of pulse width modulation to control valves such as a shut-off valve on an economizer cycle, and/or a shut-off valve on an unloader line, and/or a shut-off valve on a suction. By rapidly cycling these valves utilizing pulse width modulation techniques, additional capacity control is provided. The pulse width modulation of the internal scroll elements can also be applied in conjunction with variable speed drive operation. In this case, as known in the art, the scroll elements are separated from each other in a pulse width manner to control the amount of refrigerant pumped by the compressor. These pulse width modulation techniques for control of a valve or internal scroll compression elements have not been utilized, however, in refrigerant systems having a variable speed drive compressor.

SUMMARY OF THE INVENTION

[0007] In the disclosed embodiment of this invention, a compressor is provided with a variable speed drive. When a need for a low capacity is detected, the compressor is moved to a low speed to maintain adequate conditions in the environment without switching to a start-stop mode of operation. The compressor is incorporated into a refrigerant system, which has a pulse width modulation control for cycling some component in the system, other than cycling on and off the compressor motor. In disclosed embodiments, the cycled component is a valve, and may be a suction valve, and/or an economizer cycle shut-off valve and/or an unloader valve and/or cycled component is one of the scroll compressor pumping elements. By cycling these components on and off, the amount of refrigerant delivered to various locations in the refrigerant cycle is lowered, and thus the capacity can be lowered without lowering the compressor motor speed beyond the safe regime.

[0008] Although, for illustrative purposes, the operation of the valves in this invention is described in relation to refrigerant systems incorporating scroll compressors, it could be applicable to any variable speed compressor.

[0009] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1A is a schematic view of a refrigerant system incorporating the present invention.

[0011] FIG. 1B shows an alternative embodiment.

[0012] FIG. 2 shows another schematic of a refrigerant system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] A refrigerant system 19 is illustrated in FIG. 1 having a scroll compressor 21 incorporating a non-orbiting scroll member 22 and an orbiting scroll member 24. As is known, shaft 26 is driven by an electric motor 28 to cause the orbiting scroll member 24 to orbit. As shown, a variable speed drive 30 is schematically connected to drive the electric motor 28. An oil sump 32 and an oil passage 34 in the shaft 26 supply oil to the various moving elements in the compressor 21, as known.

[0014] A condenser 36 is positioned downstream of the compressor 21, an expansion device 38 is located downstream of the condenser 36, and an evaporator 40 is positioned downstream of the expansion device 38, as known. As is also known, the compressor 21 is driven by the electric motor 28 to compress the refrigerant vapor and to drive it through the refrigerant system 19. Oil from the oil sump 32 is delivered to the compressor elements to provide proper lubrication of the compressor components such as the crankcase bearing 100, orbiting scroll bearing 102, the non-orbiting scroll 22 and the orbiting scroll 24, while some amount of oil leaves the compressor 21 with the refrigerant and is circulated through the refrigerant system 19. One of the most typical oil delivery systems of a scroll compressor is also shown in FIG. 1, where the oil from the oil sump 32 is picked up by the oil pick up tube 110, and delivered along the oil passage 34 to various compressor components as described above. Some of the oil can also be delivered through the suction port 120 by a refrigerant entering the compressor. However most of the oil delivery is accomplished by delivering the oil from the oil sump as
described above. In the prior art, when a variable speed drive has been implemented in a refrigerant system, the designer has been limited by a minimum operational speed of the shift for the compressor. If the speed dropped below a certain level for extended period of time, an insufficient amount of oil would be delivered through the oil passage into the compressor components that need to be lubricated. Thus, for a low cooling load situation, where only a small amount of the compressed refrigerant mass flow is needed to be circulated through the system, a minimum speed requirement (for example 45 Hz) is often a limiting factor in ensuring that adequate amount of oil is provided to the compressor components. Further, the operation above a minimum speed would also ensure that the radial compliance necessary for efficient operation of the scroll compressor is not lost due to unsteady low motor speed. As known, it is important to match the delivered capacity to the system load. Since the compressor operating speed often cannot be reduced below a certain threshold for capacity shedding, additional efficient means are required to reduce the capacity delivered by the unit without cycling the unit on and off for tight temperature control within the cooled environment. The description below provides additional means of efficiently shedding the capacity by coupling the compressor variable speed operation with pulse-width modulation of different system components.

[0015] FIG. 1 shows additional features that may be incorporated into the refrigerant system 19. As an example, an economizer cycle is included and has an economizer heat exchanger 18. A main liquid line 13 has a tap line 11 that taps off of the main liquid line and passed through an economizer expansion device 115. The tap line 11 and the main liquid line 13 both pass through the economizer heat exchanger 18. In fact, and in practice, the refrigerant flow in the tap line is typically in the counterflow direction through the economizer heat exchanger in relation to the flow in the main liquid line 13. However, to simplify the illustration in this figure, they are shown in the same direction. As is known, the economizer circuit subcools the refrigerant in the main liquid line, and thus enhances performance (capacity and/or efficiency) of the refrigeration system 19. An economizer injection line 20 is shown extending back to the compressor 21, and injects an intermediate pressure refrigerant into compression chambers through passages such as passage 23. The function and structure of the economizer circuit is known, however, its inclusion with the inventive motor control 30 provides a refrigerant system that has even greater flexibility to enhance operation of the refrigeration system 19.

[0016] An optional unloader line 17 includes an unloader valve 200. The unloader valve 200 is selectively opened to return partially compressed refrigerant from the compression chambers through the passages 23 back to a suction port 120 of the compressor 21. The unloader function prevents a refrigeration system designer with an extra degree of freedom for performance adjustment and optimization. The unloader valve can be located inside or outside of the compressor, as known.

[0017] Essentially, when a greater system capacity is desired, the economizer function may be utilized with the unloader valve shut. Alternatively, if a lower capacity is necessary, the economizer expansion device 115 (or a separate shut-off device) is shut, with the unloader valve 200 opened. In this manner, the amount of compressed refrigerant delivered to the condenser 36 is reduced. Also, if desired to provide another intermediate stage of capacity for the refrigeration system 19, the economizer function can be combined with the unloader function by opening both the economizer expansion device 115 and the unloader valve 200. Shutting the flow in the economizer injection line and closing the unloader valve 200 also achieve another alternate intermediate stage of capacity unloading.

[0018] These system configurations in combination with the variable speed motor control disclosed below provides even greater freedom and flexibility to a refrigeration system designer for controlling the delivered system capacity.

[0019] In this case, the control 30 may incorporate more than a variable speed drive, but may also be a microprocessor or other type control that is capable of providing pulse width modulation control to the economizer valve 115 (which in this case would be a shut-off valve), and/or the unloader valve 200, and/or a suction modulation valve 210.

[0020] Also as known in the art, the pulse width modulation can also be used to pulse width modulate the scroll compression elements itself, in this case the scroll elements would be separated from each other in a pulse width manner to control the amount of the refrigerant pumped by the compressor.

[0021] FIG. 13 shows an embodiment 301, schematically. It is known that the orbiting scroll member 302 and the non-orbiting scroll member 304 may be biased together by a gas in a chamber 306. Opening and closing the valve 310 can control pressure in chamber 306. As shown, the valve 312 communicates via line 308 with another pressure source that is at different pressure than pressure in the chamber 306 when the valve 310 is closed. When the pressure in the chamber 306 is reduced below a certain level the scroll members will separate from each and the amount of refrigerant pumped by the compressor is then reduced. When the pressure in the chamber 306 is increased above certain level the scrolls will come into contact with each other and then the normal compression process will resume. The valve can be controlled by a pulse width modulation control 312. Thus, by modulating the pressure in the chamber 306, the two scroll members 302 and 304 can be allowed to periodically move away from, and come into contact with, each other. It should be noted that the schematic shown in FIG. 13 is presented for an illustration purpose only. For example, instead of allowing the scroll 304 to move axially in and out of contact with the scroll 302, the scroll 302 can be allowed to move axially while the scroll 304 remains essentially stationary in the axial direction. The valve 312 can be located internal or external to the compressor.

[0022] While the schematic shows the control providing pulse width modulation control to each of these valves and or compressor elements, in other embodiments any combination of the three valves and or compressor, or even other valves can be utilized. By rapidly cycling these valves to open and closed position (closing can be partial or complete), the amount of refrigerant passing through any one of the valves and compressor can be varied to vary capacity. As an example, once the compressor speed has been lowered, and additional capacity reduction is desired a valve or compressor can be cycled to further reduce the system capacity. It should be noted that normally the compressor speed reduction would be applied first to shed the capacity, since this is the most efficient means to do so than other methods of unloading.

[0023] The present invention provides efficient means to efficiently and precisely control capacity of the refrigeration system 19 by employing varying methods of pulse width modulation of various system components coupled with the use of a variable speed drive motor. The motor drive can be
varied in speed when there is a need for capacity adjustment. The economizer circuit can also be turned on or off to vary capacity. The unloader function can also be utilized. In addition, and in combination with each of the above options for this control, the present invention also allows the control to modulate the flow of refrigerant through any one of valves 115, 200 and 210 and/or through modulation of the compressor pumping element itself. In this manner, the capacity can be further reduced without unduly lowering the speed of the compressor motor 28 beyond its safe threshold of operation.

FIG. 2 shows another embodiment 300 wherein the valves 200 and 210 are internal of the compressor shell as are the flow passages. It should be noted that while in FIG. 2 the valves are all shown as located inside the compressor, a compressor designer may choose to locate some of them internally and some of them externally. In addition, the shut-off valve 220 for the economizer line is shown to be separate from the expansion valve. If the valve 220 is located externally, its function can be combined with the use of an expansion valve. Also while valves are shown as separate components, its function can be combined into a single three-way valve as known in the art. Each or some of the valves 220, 200 and 210 can be controlled by pulse width modulation techniques.

It should be understood that the motor control 30 includes a program that takes in inputs from various locations within the refrigerant system, and determines when a lower speed for the compressor motor would be desirable and when the pulse width modulation of the pulse width modulated components needs to be initiated. The controller can also decide when the system needs to be operated in economized, non-economized, and by-pass unloading modes or any of its combinations as described above. Controls capable of performing this invention with such valves and compressors are known.

A worker of ordinary skill in the art would recognize when a lower speed might be desirable and preferred in comparison or in addition to other available options.

It should be understood that although this invention is described in relation to refrigerant systems incorporating scroll compressors, it could be applicable to any variable speed compressor, including scroll compressors, screw compressors, reciprocating compressors, rotary compressors, etc. The application of this technique can for example, be applied to refrigeration systems used in transportation container units, truck/trailer application, supermarket refrigeration application, as well as cooling or heating industrial buildings and residential houses as well as used for water heating applications. Although a preferred embodiment of this invention has been disclosed, a worker of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

1. A refrigerant system comprising:
   - a compressor and an electric motor for driving said compressor, a variable speed drive for varying a speed of operation of said electric motor;
   - a condenser downstream of said compressor, an expansion device downstream of said condenser, and an evaporator downstream of said expansion device;
   - said variable speed drive moving said motor to low speed operation, and said variable speed drive operating said motor at a low level of speed; and
   - a pulse width modulation control for controlling at least one system component.
2. The refrigerant system as set forth in claim 1, wherein said pulse width modulation control controls at least one valve.
3. The refrigerant system as set forth in claim 2, wherein an economizer circuit is incorporated into the refrigerant system.
4. The refrigerant system as set forth in claim 3, wherein the said at least one system component is a shut-off valve associated with said economizer circuit.
5. The refrigerant system as set forth in claim 2, wherein said compressor is provided with an unloader circuit.
6. The refrigerant system as set forth in claim 5, wherein said at least one system component is a valve associated with said unloader circuit.
7. The refrigerant system as set forth in claim 2, wherein the refrigerant system is provided with both an economizer circuit and an unloader circuit.
8. The refrigerant system as set forth in claim 7, wherein said at least one system component includes a valve associated with said economizer circuit and a valve associated with said unloader circuit.
9. The refrigerant system as set forth in claim 2, wherein said at least one system component is a valve for controlling the mass flow of refrigerant delivered to said compressor from said evaporator.
10. The refrigerant system as set forth in claim 1, wherein said at least one system component is external to a shell for said compressor.
11. The refrigerant system as set forth in claim 1, wherein said at least one system component is internal to a shell for said compressor.
12. The refrigerant system as set forth in claim 1, wherein said compressor is selected from the group consisting of a scroll compressor, a rotary compressor, a reciprocating compressor, and a screw compressor.
13. The refrigerant system as set forth in claim 1, wherein said at least one component is a pulse width modulated control to hold the orbiting and non-orbiting scroll member in a scroll compressor together or allow them to move away from each other.
14. The refrigerant system as set forth in claim 1, wherein said system is selected from the group consisting of a container refrigeration system, a truck/trailer system, a supermarket refrigeration system, a residential air conditioning system, a residential heat pump system, a commercial air conditioning system, a commercial heat pump system, and a water heating system.
15. A method of operating a refrigerant system comprising the steps of:
   (1) providing a compressor with a variable speed drive, and monitoring a load on a refrigerant system associated with said compressor;
   (2) identifying a low load situation, and moving said compressor to a low speed operation when a low load situation has been identified; and
   (3) providing pulse width modulation control for a system component to allow the variation of capacity from the refrigerant system by both varying the speed of the compressor, and varying the operation of said other component.
16. The method as set forth in claim 15, wherein said pulse width modulation control controls at least one valve.
17. The method as set forth in claim 16, wherein an economizer circuit is incorporated into the refrigerant system, and said at least one system component associated with a shut-off valve associated with said economizer circuit.

18. The method as set forth in claim 16, wherein said compressor is provided with an unloader circuit, and said at least one system component associated with a valve associated with said unloader circuit.

19. The method as set forth in claim 16, wherein the refrigerant system is provided with both an economizer circuit and an unloader circuit, and said at least one system component includes a valve associated with said economizer circuit and a valve associated with said unloader circuit.

20. The method as set forth in claim 15, wherein said at least one component is external to a shell for said compressor.

21. The method as set forth in claim 15, wherein said at least one component is internal to a shell for said compressor.

22. The method as set forth in claim 15, wherein said other component is a valve for controlling the amount of refrigerant delivered to said compressor from said evaporator.

23. The method as set forth in claim 15, wherein said at least one component is a pulse width modulated control to hold the orbiting and non-orbiting scroll member in a scroll compressor together or allow them to move away from each other.

* * * * *