AAON®

Defining Quality. Building Comfort.

Variable Flow Primary Pumping

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VARIABLE FLOW PRIMARY PUMPING CHILLED WATER SYSTEM

Variable flow primary pumping systems utilize a variable capacity cooling system and a variable flow water pumping system to modulate cooling and water flow to meet chilled water needs and save operating energy costs. Cooling capacity is modulated with variable capacity compressors based on the desired leaving water temperature. Water flow is modulated with VFD controlled variable flow primary pumps based on the differential pressure across the water system.

Benefits

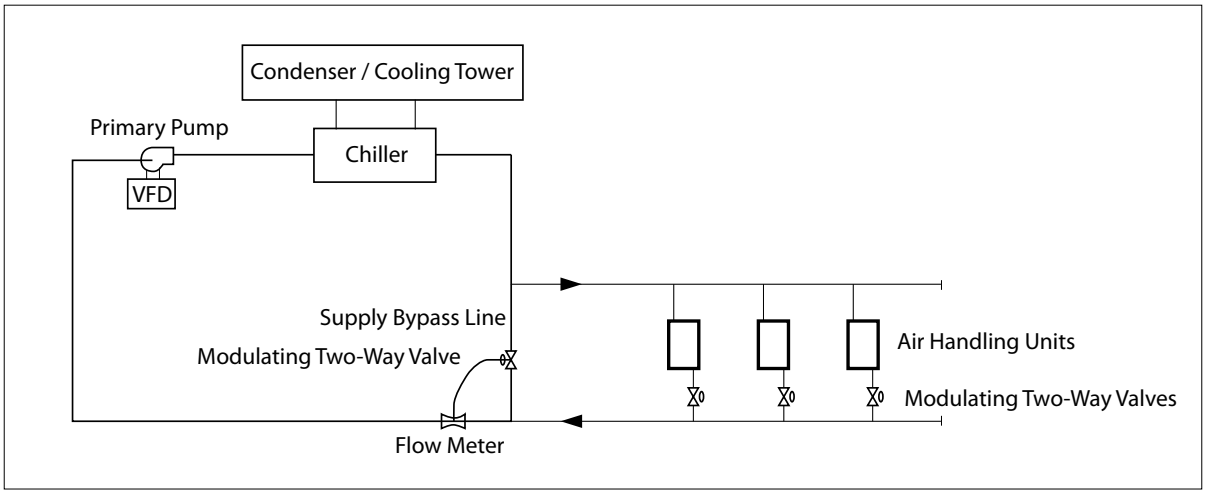
Constant flow pumping systems traditionally utilize a staged cooling system and a constant flow water pumping system. Variable flow primary pumping systems save energy compared with constant flow pumping systems during part load operation because water flow is reduced and less pump energy is required. In addition, with reduced water flow during part load operation, less compressor energy is required. Installation costs for constant flow pumping systems and variable flow primary pumping systems are similar because only an additional pump VFD is required in the variable flow primary pumping system.

Constant flow primary/variable flow secondary pumping systems utilize a variable capacity cooling system, a constant flow primary pumping water system (production) and a variable flow secondary pumping water system (distribution). Variable flow primary pumping systems save energy compared with primary/secondary pumping systems because during part load operation water flow is reduced in both the production and distribution of the chilled water and thus less total pump energy is required. Also, less pump energy is required because no secondary pump water valves, fittings, strainers and other secondary pumping water system components are required. Installation costs and ongoing maintenance costs for variable flow primary pumping systems are less than with primary/secondary pumping systems because secondary pumps and secondary pumping system components are not included in the system. Usable building space can be saved, or the size of the mechanical room can be reduced, with variable flow primary pumping systems because space for secondary pumps and secondary pump system components are not required. The control and power wiring for secondary pumps is also not required.

The variable flow primary pumping system is the most economical and energy efficient chilled water system available.

Applications

All applications which require chilled water can benefit from the performance optimization and operating cost savings of variable flow primary pumping. A wide range of sizes of variable capacity compressors, variable speed pumps and variable speed condenser fans allow variable flow primary pumping to be applied in numerous applications. The packaged design of an AAON variable flow primary pumping system, with the chiller, condenser, water pumping and controls included, makes variable flow primary pumping ideal for new or retrofit applications.



Variable Flow Primary Pumping System

Variable Flow Primary Pumping System

A chilled water system consists of a condenser, chiller and chilled water loop. In a variable flow primary pumping system, the condenser, chiller and chilled water loop all work together to maximize efficiency and performance. The chiller varies its cooling capacity to maintain a desired chiller leaving water temperature, which saves compressor energy at part load conditions. The condenser varies its condensing capacity to maintain a refrigerant head pressure, which optimizes chiller performance and saves fan energy. The primary pumping system, which functions as both the production and distribution systems, varies its pumping capacity to maintain a differential pressure across the chilled water loop, which saves pump energy at part load conditions.

Challenges

For a variable flow primary pumping chiller system to perform optimally the system must be able maintain a minimum flow rate through the chiller, have quick unloading cooling capacity and have condenser head pressure control. These challenges can be overcome with a precise control system, variable speed condenser/cooling tower fans, variable capacity compressors, variable speed water pumps and a supply water bypass line.

Variable Capacity Chiller

A chiller operating in a variable flow primary pumping chilled water system varies its cooling capacity to save energy at part load conditions. Maintaining a desired leaving water temperature optimizes the performance of the system.

Methods of cooling capacity modulation for a chiller system are multiple chillers, a multi-stage chiller, a chiller with hot gas bypass or a chiller with variable capacity compressors. Multiple chillers and multi-stage chillers are limited by a finite number of capacity steps. During all loading conditions outside these capacity steps the system will not operate efficiently. Hot gas bypass does not save energy because during part load operation the chiller will be false loaded with the bypassed hot refrigerant gas.

The most energy efficient method of cooling capacity modulation is using variable capacity compressors. At a reduced capacity variable capacity compressors use less energy. Variable capacity compressors also have quick unloading capabilities,

Variable Capacity Scroll Compressor

which allow the system to maintain a consistent leaving water temperature and prevent nuisance trips of the chiller system safeties. Finally, with a wide range of capacity modulation, variable capacity compressors have a wide range of energy efficient part load operation capabilities.

Variable Capacity Oil-Free Magnetic Bearing Centrifugal Compressor

High Performance Condenser

The condenser of a variable flow primary pumping chilled water system varies its capacity to save energy at all ambient and load conditions. Maintaining the refrigerant head pressure of a chiller with variable capacity compressors optimizes the performance of the system. Air-cooled condensers operate at the ambient dry bulb temperature and at off-design conditions the condenser fans reduce speed and airflow, saving fan motor energy. Evaporative-cooled condensers and water-cooled condensers, when connected to a cooling tower, operate at the ambient wet bulb temperature; at off-design conditions the condenser/cooling tower fans reduce speed and airflow, saving fan motor energy.

Air-Cooled Condenser

Fan Energy Saving

As the ambient temperatures decreases, the refrigerant head pressure of the condenser decreases. To maintain the desired head pressure the condenser airflow is reduced by the reducing the speed of the condenser fans. Condenser fan speed control is accomplished with ECM driven or VFD controlled fans. According to the fan laws, less energy is required to operate a fan at a lower speed.

$$N_2 = N_1 \bullet (Q_2/Q_1)$$

$$HP_2 = HP_1 \bullet (N_2/N_1)^3 \bullet (\rho_2/\rho_1)$$

$$HP_2 = HP_1 \bullet (N_2/N_1)^3$$

N = Fan Speed (rpm)
Q =Airflow (cfm)
HP =Fan Power (hp)
ρ = Air Density

Assuming the air density does not change, the fan speed is directly proportional to the fan airflow and the fan power input is proportional to the cube of the fan rotational speed. Conditions which require only 50% of the condenser fan design airflow, would require only 12.5% the condenser fan horsepower.

Evaporative-Cooled Condenser

Variable Flow Primary Pumps

The primary pumps of a variable flow primary pumping chilled water system vary the water flow through the chiller and to the chilled water loop to save energy at part load conditions. The primary pumping water system acts as both the production and distribution pumping system and varies pumping capacity to maintain a differential pressure across the chilled water loop.

Reducing water flow through the complete system saves pump energy because only the water flow required by the load is chilled and delivered. With a variable flow primary pumping system, at the majority of loading conditions no chilled water is returned back to the chiller, without being used by the load.

The ability to vary the water flow through the chiller has many benefits. It allows production pump energy savings and compressor energy savings during part load operation. The quick unloading capabilities of variable capacity compressors makes varying water flow through the chiller possible, because a consistent leaving water temperature can be maintained over a variety of loading conditions. This reduces the likelihood of nuisance trips of the chiller safeties, which prevent the chiller from freezing, and it also optimizes performance of the chiller system.

A supply water bypass with modulating valve and return water flow sensor is required with variable flow primary pumping systems. During low load conditions this system ensures a minimum water flow through the chiller. The modulating valve and return water flow sensor only allow the bypass to be used at low load conditions to maximize energy efficiency at other loading conditions.

An additional benefit of the ability to vary the water flow through the chiller is to minimize the efficiency losses during "low ΔT syndrome" conditions. A low ΔT across the chiller (Entering Water Temperature - Leaving Water Temperature) can be caused by improper coil and control valve selections, dirty coils, laminar coil flow, mismatched design conditions, use of three-way valves, improper setpoints, improper coil piping, use of outside air economizers and chilled water mixing. To combat a low ΔT a variable flow primary pumping system can vary the water flow through the chiller to optimize efficiency. This solution is not possible with any other pumping system.

Pump Energy Saving

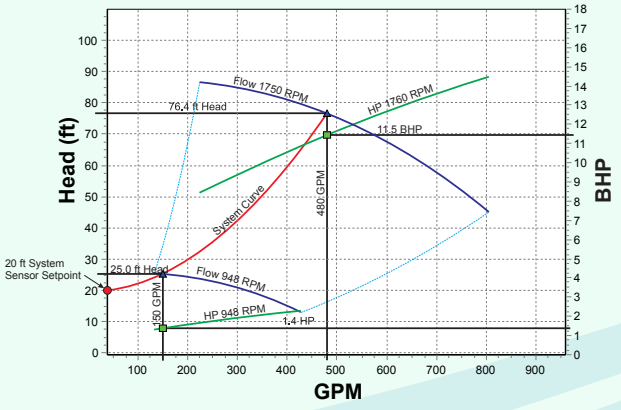
As the load on the chilled water system is reduced, the water flow through the chiller (production) and to the load (distribution) is reduced. Reducing the speed of the centrifugal primary pumps, with pump VFDs, reduces the water flow. Less energy is required to operate a pump at a lower speed.

EXAMPLE

A building includes a single 200 ton chiller with variable flow primary pumping and twenty 4,000 cfm chilled water air handling units. At design conditions, each air handling unit requires 24 gpm of 44°F chilled water and the chiller provides 480 gpm of 44°F chilled water with a 1760 rpm water pump at 11.5 bhp.

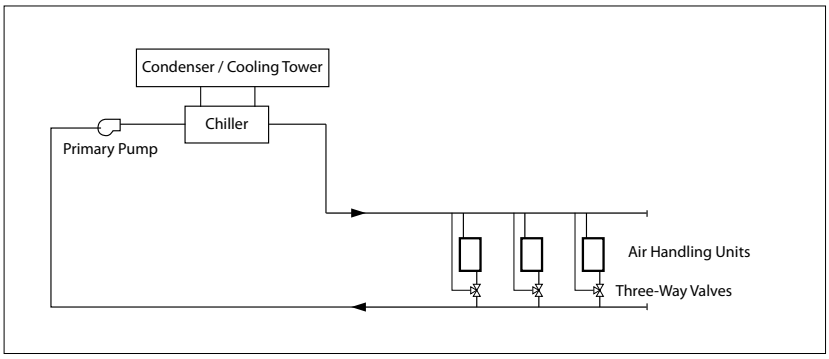
Now, assume a part load condition when only 5 of the 20 air handling units require cooling. The chilled water required is only approximately 30% of the design water flow, or 150 gpm at 44°F.

Using the performance curve of the primary pump shown below, as the speed of the pump is reduced to 948 rpm with a VFD, the flow is reduced to 150 gpm and the required brake horsepower is reduced from 11.5 bhp to 1.4 bhp.



Constant Flow Pumping compared with Variable Flow Primary Pumping

Constant flow pumping systems utilize a variable capacity cooling system and a constant flow water pumping system. Cooling capacity is modulated based on the desired leaving water temperature. Water constantly flows through the system.



Constant Flow Pumping System

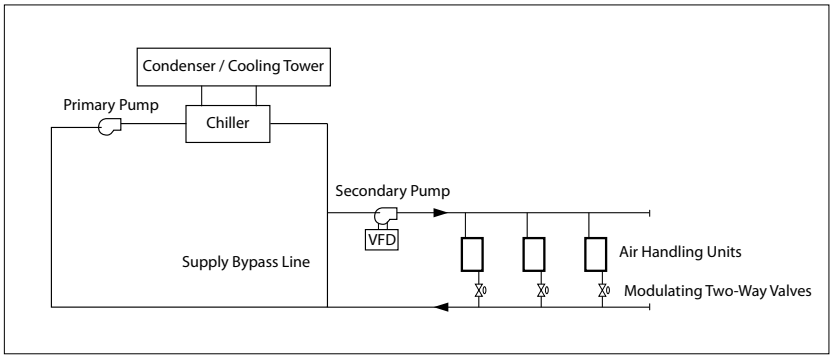
Variable flow primary pumping saves pump energy by reducing water flow through the system with VFD controlled pumps during part load operation. With less water flowing through the chiller, variable flow primary pumping also saves compressor energy with variable capacity compressors. Installation costs are similar; the additional required component is the pump VFD in the variable flow system. Variable flow primary pumping can also minimize efficiency losses during "low ΔT syndrome" conditions because of the ability to vary water flow through the chiller.

Constant Flow Primary/Variable Flow Secondary Pumping compared with Variable Flow Primary Pumping

Constant flow primary/variable flow secondary pumping systems utilize a variable capacity cooling system, a constant flow primary pumping system (production) and a variable flow secondary pumping system (distribution). Cooling capacity is modulated based on the desired leaving water temperature. Water constantly flows through the chiller. Water flow to the load is modulated based on the differential pressure across the chilled water loop.

During part load operation variable flow primary pumping systems save additional pump energy, compared with constant flow primary/variable flow secondary systems, by reducing water flow in both the chilled water production and distribution loops with VFD controlled primary pumps. Pump energy is also saved because there are no secondary pump water valves, fittings, strainers and other secondary pumping water system components to overcome. With less water flowing through the chiller, variable flow primary pumping also saves compressor energy with variable capacity compressors. Variable flow primary pumping can also minimize efficiency losses during "low ΔT syndrome" conditions because of the ability to vary water flow through the chiller. Variable flow primary pumping systems always use less energy than primary/secondary systems.

In addition to energy savings, variable flow primary pumping also has other benefits when compared with primary/secondary pumping. Because secondary pumps and secondary



Constant Flow Primary/Variable Flow Secondary Pumping System

pump water system components are not required usable building space can be saved, or the size of the mechanical room can be reduced, with a variable flow primary pumping system. The control and power wiring for the secondary pumps is also not required. Installation costs and ongoing maintenance costs are less because there are no secondary pumps or secondary pump water system components to install or maintain.

VARIABLE FLOW PRIMARY PUMPING SYSTEM

Variable flow primary pumping systems utilize a variable capacity chiller, a high performance condenser and variable flow primary water pumping to meet chilled water needs. The modulating capabilities optimize the performance of the chilled water system and save operating energy costs at all conditions. Variable flow primary pumping is the most economical and energy efficient chilled water system available.

Challenges

A variable flow primary pumping system must be able to maintain a minimum water flow rate through the chiller, have quick and energy efficient unloading capacity and be able to maintain condenser head pressure.

AAON Solutions

To maintain a minimum water flow rate through the chiller, variable flow primary pumping systems include VFD controlled variable speed primary pumps and a supply water bypass line. The bypass line includes a modulating valve and return water flow meter to ensure the bypass operates only at the lowest loading conditions. Variable capacity scroll or centrifugal compressors provide the variable flow primary pumping chiller system with quick and energy efficient unloading capabilities over a wide range of capacities. To maintain condenser head pressure and optimize performance, variable flow primary pumping systems include ECM driven or VFD controlled variable speed condenser fans.

Variable flow primary pumping chilled water systems are available as a packaged outdoor mechanical room with factory provided and factory engineered chiller, condenser, primary pumping package and controller. This packaged design saves valuable interior building space and reduces installation and maintenance costs

Benefits

The variable flow primary pumping system optimizes the performance of a chilled water system and saving operating energy. All applications which require chilled water can benefit from performance optimization. With the availability of a wide range of variable capacity compressor, variable speed pump and variable speed condenser fan sizes, variable flow primary pumping can be used for small or large applications. The packaged outdoor mechanical room design with chiller, condenser, water pumping and controls makes the variable flow primary pumping system ideal for new or retrofit application.

Contact your local AAON Sales Representative to specify an AAON variable flow primary pumping system.

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