

The background is a night-time photograph of a city street corner. A prominent building has a curved facade with a glass and metal structure. The scene is overlaid with various digital elements: glowing blue lines representing data or energy flow, circular icons for electricity, temperature, and fire, and a large semi-transparent window displaying a technical schematic and a line graph. The overall color palette is dominated by blues and teals, with warm yellow and orange light trails from traffic in the foreground.

**SIEMENS**  
*Ingenuity for life*

# Hydronic Flow Optimization

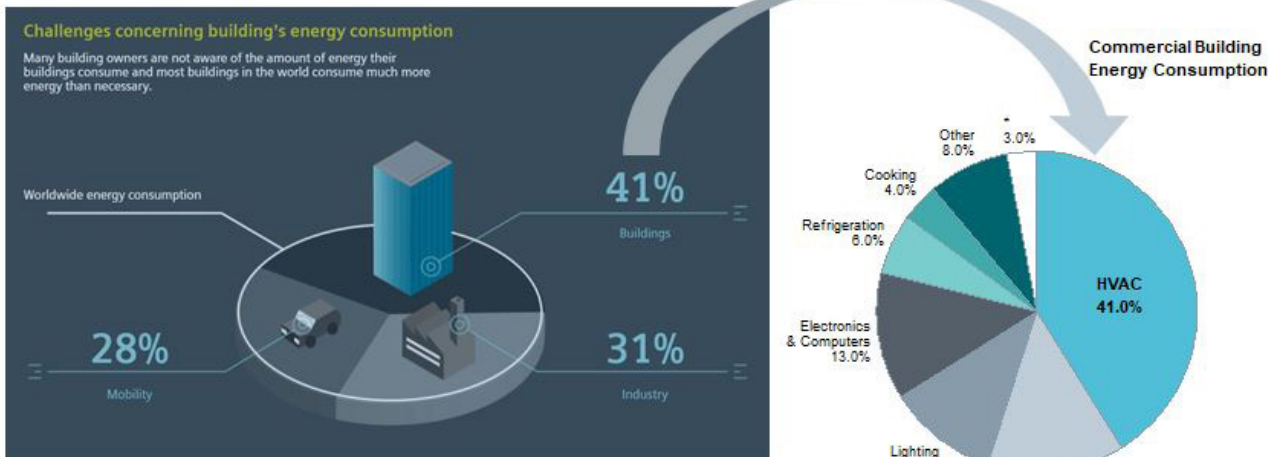


# » Hydronic Flow Optimization

Out of worldwide energy consumption, mobility (transportation) accounts for 28% of use, industry accounts for 31%, but buildings take the lead at consuming 41% of worldwide energy.

Looking at a typical commercial building energy use: electronics and computers account for 13%, lighting 11%, and water heating 14%. However, HVAC systems takes the lead accounting for 41% of total usage. Hydronic flow optimization is a prime way to reduce HVAC energy consumption while increasing overall building efficiency and operational performance.

Engineering firms specify an average of \$2.1 million in hydronic systems annually. These consulting and specifying engineers primarily specify, design, or select hydronic systems for projects involving office buildings, college/university campuses, government or military complexes, hospitals/health care facilities, and industrial/manufacturing facilities/warehouses.



Although there are other criteria, the main factor engineers

# » *Hydronic Flow Optimization*

consider when designing hydronic systems is energy efficiency. In addition, energy efficiency is a primary factor for engineers who would consider switching hydronic system component providers/manufacturers.

As consulting and specifying engineers, you are continually looking to deliver value to your clients. A great way to do that is by providing energy efficiency through optimization of hydronic systems.

## **Hydronics**

Hydronics is the use of a liquid heat-transfer medium, such as water or a mixture of water and glycol in heating and cooling systems. A hydronic system may include both a chilled and a heated water loop to provide both heating and air conditioning. Chillers and cooling towers are used either separately or together as means to provide water cooling, while boilers heat water.

Although hydronic systems can be more complex, the components in common with a simple hydronic system include:

- Boilers and chillers
- Primary pumps
- Control valve
- Loads (radiators or heat exchangers)

# » Hydronic Flow Optimization

- Differential pressure sensors
- Flow sensors
- and more

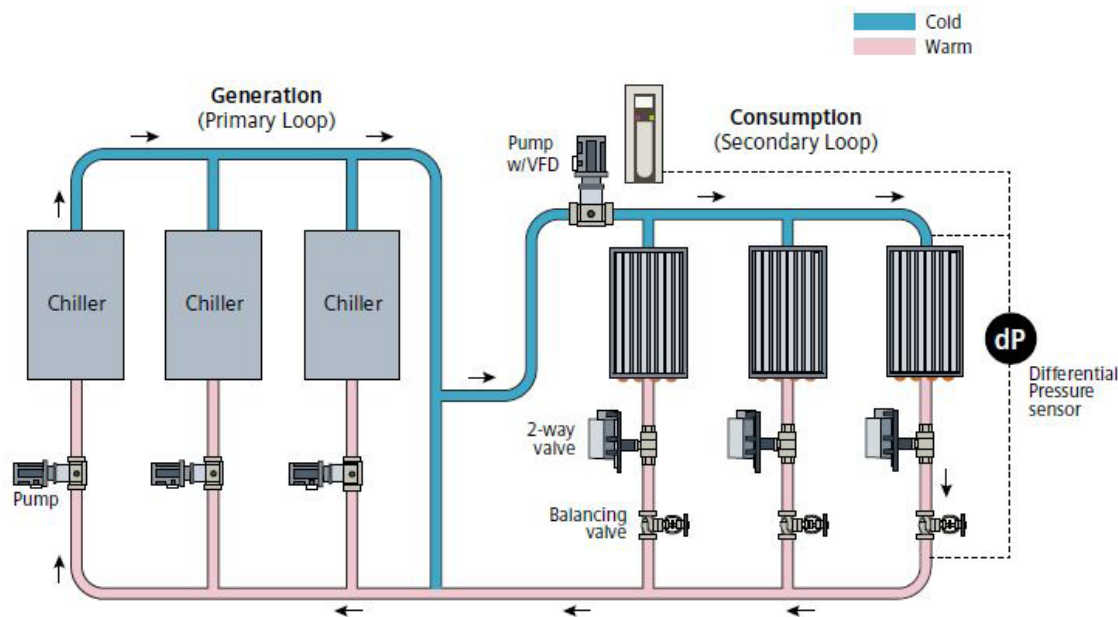
## Design Evolution

Older constant volume systems designs use considerable energy compared to more modern methods because pumps see a relatively constant head pressure having to continuously pump water throughout the entire piping network.

A variable volume secondary design enables the distribution of chilled water to the

consumption coils that are decoupled from the generation or primary loop. The advantage is that a secondary pump is used with a VFD to control flow, which allows a 2-way valve to be used instead of a 3-way valve at the consumption coils. The benefit of variable flow secondary is that the pumping energy is greatly reduced to

**Figure 1:** Variable Flow secondary loop with 2-way valves





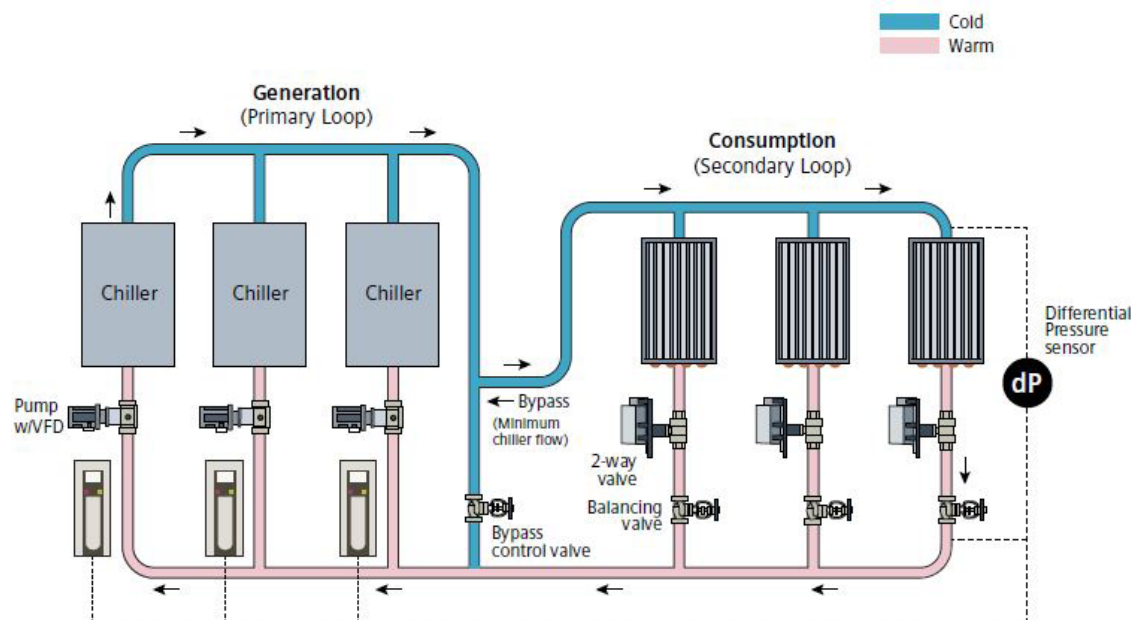
# » Hydronic Flow Optimization

just the flows needed to each load. However, a balancing valve is still required to balance the secondary circuits.

A variable primary volume design still maintains a generation or primary loop and a consumption or secondary loop. With this configuration, the chillers are selected so that they can unload with variable flow through the chillers. Each chiller gets its own VFD on its respective pump. The bypass now gets a control valve that effectively directs water

into the consumption or secondary loop. The advantage of the variable primary volume design is that only what is needed is pumped through the chillers and the bypass control valve directs the flow to the consumption or secondary loop. The entire distribution piping network is seeing only the flow it

**Figure 2:** Variable Flow primary loop with 2-way control valves



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needs when it needs it, effectively reducing any unnecessary head losses in the system. This allows a 2-way valve to be used instead of a 3-way valve at the consumption coils. This allows us to move away from a 3-way valve to a 2-way valve at the consumption coils, and a balancing valve will still be required to balance the secondary circuits.

## **Avoiding overflow:**

### **Different resistance leads to under or over supply**

In hydronic heating and cooling systems, the hot or cold medium distributing the thermal energy from its generation to the consumer (water, either plain or mixed with an agent like glycol) is transported over piping sections of different lengths and diameters. In the case of multi-story buildings, the elevation to overcome also may vary. As a consequence, the hydraulic resistance along the path from the energy generator to each terminal unit is different.

To provide the required heating or cooling, each terminal unit is designed for a certain flow. When the flow is too low, the consumer does not receive enough energy (undersupply). In the opposite case, when an overflow (or oversupply) takes place, the flow is so high that the terminal unit cannot sufficiently exchange the thermal energy provided, resulting in a low delta T (Delta T = Return Temp. - Supply Temp.) As a consequence, the excess energy is sent back to the energy generator, resulting in equipment operating at reduced efficiency.

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## **Hydronic balancing**

Hydronic balancing is the process of optimizing the distribution of water or fluid in a building's hydronic heating or cooling system by equalizing the system pressure to optimize energy efficiency, provide occupant comfort and lower operating cost.

## **The differences are normalized with static balancing**

To ensure that every consumer receives the proper amount of heating/cooling energy, hydraulic resistance is introduced into the system. This so-called balancing is done by installing manual balancing valves (MBVs), which are installed in series to the standard regulator valves. In this method, the hydraulic resistance of the MBVs is dimensioned so that the system is perfectly balanced for nominal operating condition. The system is “statically balanced.” However, this can only be achieved for one given “ideal” operating condition.

## **Overflow still happens in spite of static balancing**

The reality looks quite different. In statically balanced systems, overflow may still occur in certain part-load conditions. For example, if some of the circuits are only half open (part-load condition) and the rest are fully open (full-load condition), an overflow takes place in the latter circuits, which get excessive energy. Pressure fluctuations in hydronic systems are inevitable.



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An overflow might last for quite some time before the room temperature controller reacts to the increased or decreased temperature. Such transient overflow phases usually occur either due to a change of load (e.g., change of occupancy of a room) or due to a change of setpoint (e.g., start-up phase in the morning).

## **Overflow leads to energy inefficiencies**

Depending on the type of energy generators, this overflow may lead to two negative side effects.

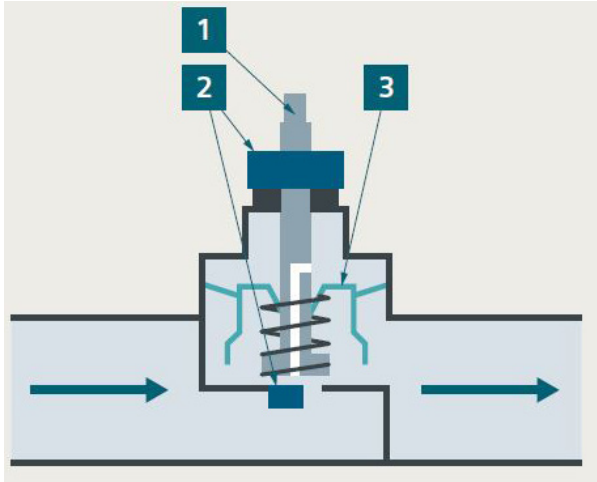
First, overflow leads to the transportation of water through the system that doesn't carry a proper amount of additional energy to the consumers (because heat transfer by the heat exchanger is directly proportional to the flow rate and the temperature difference across the heat exchanger. Flow rate and temperature difference are inversely proportional to each other in a closed system), and hence a low temperature difference across the heat exchanger.

Second, in the case of chillers and heat pumps, overflow causes inefficiencies in the energy generators. Overflow of dedicated consumers can lead to a return temperature lower than the nominal design value in cooling mode and a return temperature higher than the nominal design value in heating mode, decreasing the energy efficiency of boilers and chillers by 2% and 3%, respectively because a decrease of the evaporation temperature of a chiller below its design value by 1° decreases its performance by around 3%.



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**Figure 3:** Dynamic-balancing against pressure differences



1. Flow control valve
2. Pre-setting
3. Differential pressure regulator

pressure changes in the system and flow is determined only by the travel of the control valve. When used with a terminal unit, PICVs ensure proper flow, optimizing heat transfer and system performance.

## **Dynamic-balancing against pressure differences**

One of the ways to address the inevitable pressure fluctuations in hydronic systems is through the use of Pressure-independent control valves, or PICVs. Within their range of operation, they are not affected by pressure fluctuations in the building's hydronic system. This is called dynamic-balancing or auto-balancing.

This basic functionality is achieved by an internal differential pressure regulator working in series with the main flow control valve and regulating the pressure differential of the flow control valve using a pressure inlet and membrane. Hence the flow across the entire device is independent of the

# » *PIC valves*

## **PICVs are relevant in the whole hydronic system**

PICVs can be used in almost all heating and cooling applications in a building.

The most typical are:

### **Consumption**

- Chilled beams
- Radiators
- Zone
- Fan coil units
- Variable air volume systems

### **Distribution**

- Air Handling Units
- Pumps

### **Enabling energy savings**

In building heating and cooling applications, the auto-balancing function generates energy savings in three different ways:

- It eliminates heat exchanger overflow at any time and under any operating condition
- It improves control accuracy by eliminating hydraulic pressure dependency between neighboring control loops
- It enables advanced energy distribution strategies by eliminating the risk of heat exchanger starvation.



# » PIC valves

**Here is a list of Siemens PICV advantages:**

## **1. Automatic differential pressure regulator**

- Automatically adjusts to pressure fluctuations in the system, maintaining consistent flow at any given control setting, providing better comfort and lower energy consumption
- No mutual hydronic interaction between branches with different operational situations, preventing over or under supply
- Fast commissioning with extremely simplified hydronic balancing

## **2. Field-adjustable flow limiter**

- Full stroke always maintained with independent flow limiter enabling higher control accuracy
- Easily adjusts maximum flow to prevent overflow

## **3. Valve actuator**

- Spring return and non-spring return actuators to meet most requirements
- Visual position indication
- Manual override



# » PIC valves

## 4. Control valve

- A comprehensive portfolio of ½ inch to 6-inch PICVs
- Threaded valves are ANSI Class 250
- Flanged valves available in ANSI Class 125 and 250
- 200, 100, and 45 psi close-offs with ANSI Class IV leakage
- Brass trim with stainless-steel stem.

## 5. Optional pressure/temperature test points

- Straightforward testing and setting of optimum differential pressure when commissioning
- Allow simplified troubleshooting during system operation.

Video: Pressure Independent control valves:  
Hydronics made easy



Uniquely designed with three functions integrated into one single device: control valve, adjustable flow limiter, and automatic pressure regulator. This 3-in-1 device improves accuracy and reliability regardless of pressure fluctuations.

### How the Siemens PICV works

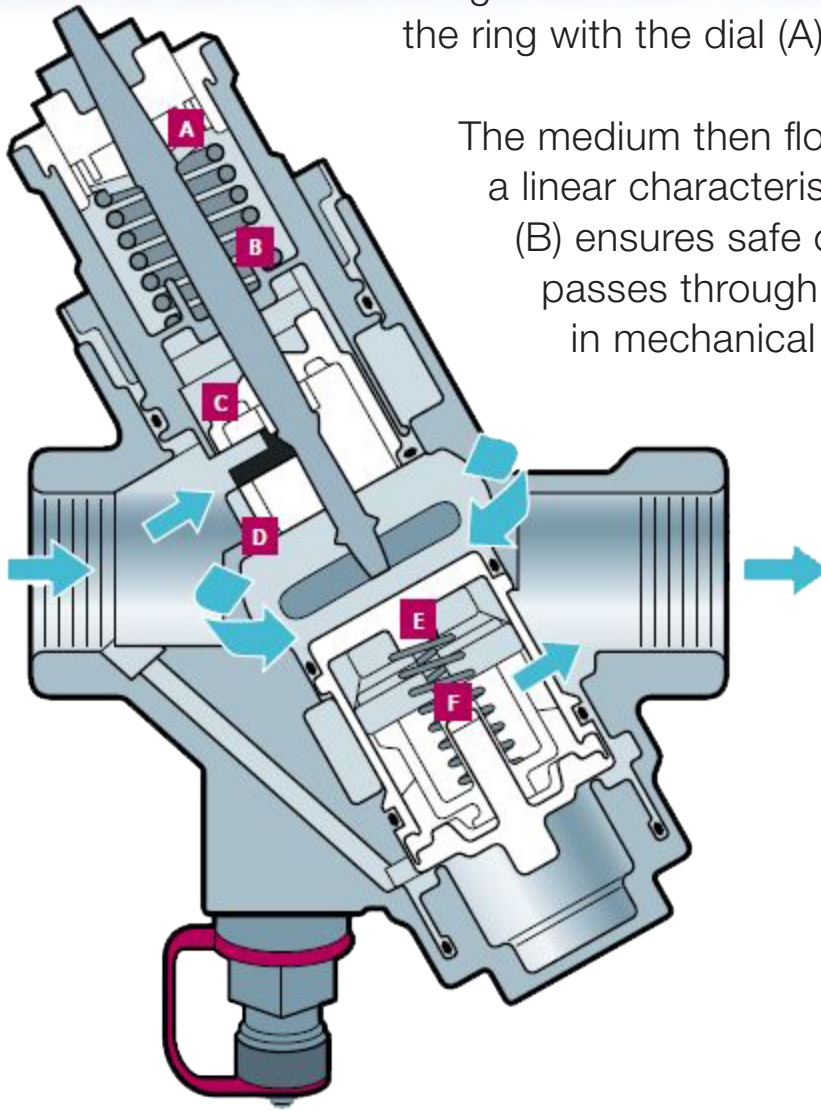
Hot/chilled water or 50% water-glycol solutions in closed loop systems enter the valve and pass



# » PIC valves

through a variable rectangular adjustable flow limiter (C) that is connected to the ring with the dial (A) for presetting the maximum volumetric flow.

The medium then flows through the temperature control valve (D) with a linear characteristic and a stroke of 5 or 6.5 mm. A powerful spring (B) ensures safe closing. Before leaving the valve, the medium passes through a second throttling point (E) controlled by the built-in mechanical automatic differential pressure regulator (F).



This regulator is the heart of the valve and ensures that the selected volumetric flow is maintained across the whole differential pressure working range.

- A:** Presetting dial
- B:** Closing spring
- C:** Throttling point linked to **A**
- D:** Control seat and plug
- E:** Pressure regulator's throttling point
- F:** Differential pressure regulator
- ➔ Flow path

# » VFDs

**R**educing the speed of pump motors using VFDs lowers energy costs by reducing the amount of energy it takes to operate the pumps.

A VFD often is specified to save money by reducing energy consumption in pumps or other motor loads that may be found in a typical building.

The following best practices provide engineers with information on how to specify a VFD to meet load conditions while achieving efficiency.

To effectively specify a VFD, engineers must understand these key points:

- Understand the load (operating power, torque, and speed characteristics)
  - Understand duty cycle (percentage of operation at 100% load, 50% load, etc.)
  - Determine the benefits desired by using a VFD (energy savings, soft start, controllability, etc.).



Understanding the load is the first step to determining what can be gained by employing VFDs. In building hydronic systems, the most common type of motor providing power to a load is a 3-phase AC induction motor. For a given power rating, the motor base speed is inversely proportional to the effective torque rating for that motor.



## » VFDs

For example, selection of an 1,800 rpm versus a 1,200 rpm motor reduces torque by a third.

Once a load's starting requirements are determined, the next step is looking at the load's running requirements. In building systems, excluding constant horsepower and constant speed/torque loads, typical loads that can take advantage of VFDs are:

- Variable speed, variable torque (fans, blowers, and centrifugal pumps)
- Variable speed, constant torque (positive displacement loads, such as screw compressors, reciprocating compressors, or elevators).

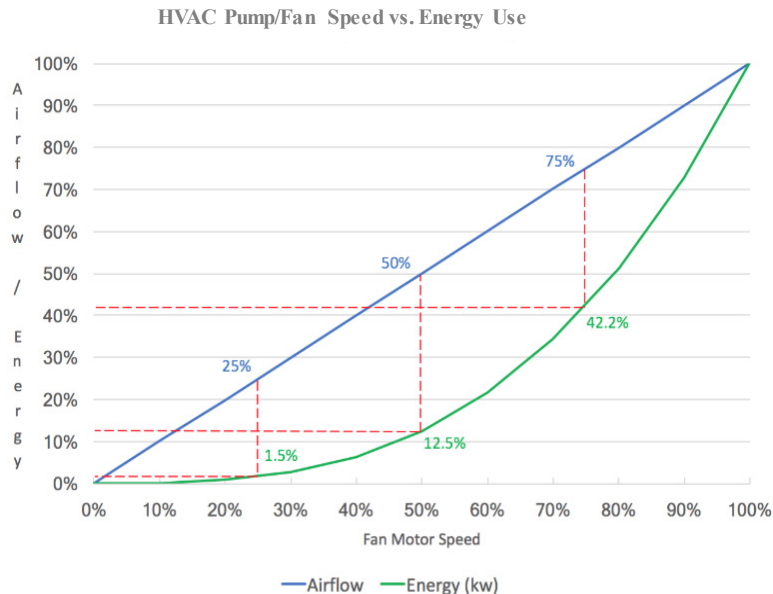
To support a characteristic load, select a motor to meet a specific starting requirement and running output power, torque, and speed.

However, because of the affinity laws, there are significant potential energy savings associated with reducing a motor's speed and, by association, horsepower. If we can define the required change in motor speed to meet the change in flow for a centrifugal load, the change in required power is proportional to the cube of the change in speed from one system point to another. The change in required torque is proportional to the square of the change in speed from one system point to another.

This nonlinear relationship between power and speed can be exploited for significant energy savings if the speed of the motor can be changed.

# » VFDs

**Figure 4:** HVAC Pump/Fan Speed vs. Energy Use



For example, if the speed of the motor is reduced by just 5% from full load, a realization of 14% energy savings is possible. When the speed of the motor is reduced to 80% from full load, 49% energy savings can be realized. Every incremental slowdown of the speed of the pump becomes more valuable from an energy savings standpoint.

For centrifugal loads, there is potential to significantly increase energy efficiency by reducing motor speed.

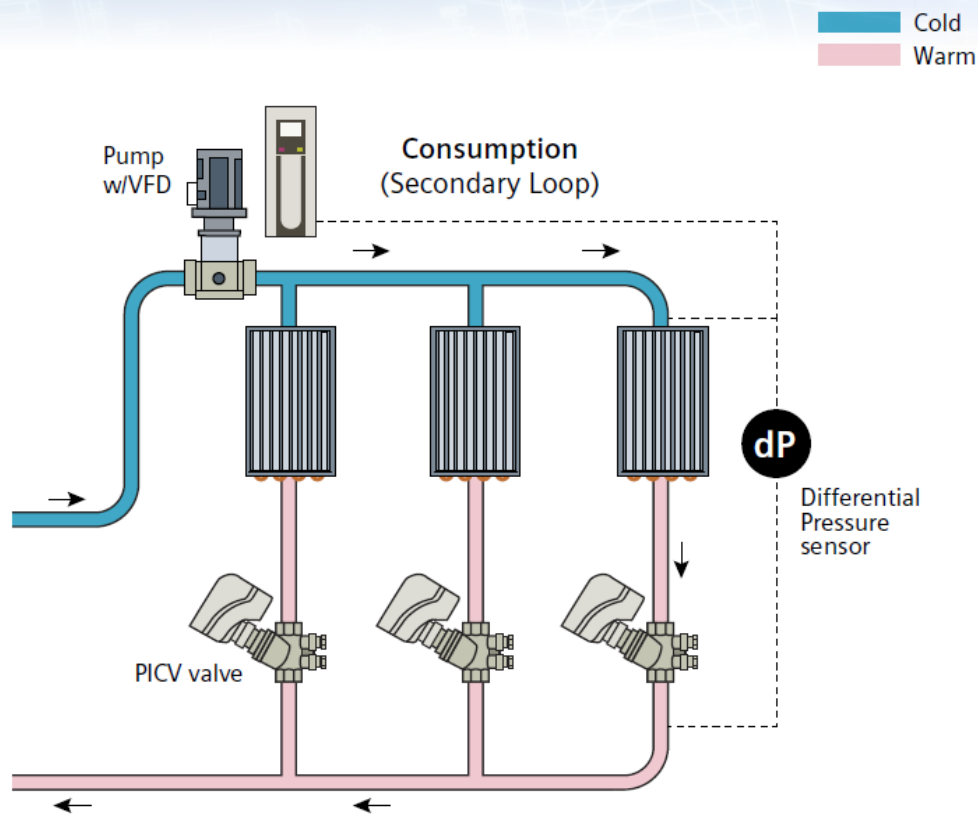
## The Hydronic System: Differential Pressure Control

As Hydronic systems continue to evolve from constant volume systems to constant volume primary, variable volume secondary, to variable primary systems it is important to ensure we maintain flow across all of our heat transfer circuits. Since a VFD is connected to either the primary pumps or secondary pumps in variable hydronic flow systems, the control loop will need an input to monitor and control. A differential pressure sensor located on the circuit most likely to be starved, also known as the critical circuit, is a common and reliable input configuration. The differential pressure sensor will allow the hydronic system to set a minimum pressure across the critical circuit ensuring flow availability across



# » VFDs

**Figure 5:** Variable Flow secondary with PICVs



all circuits. The pump and variable frequency drive will take the differential pressure measurement across the critical circuit and control via the VFD's onboard proportional-integral-derivative (PID) controller, allowing the pump speed to be optimally reduced and energy savings maximized.

## Hydronic flow optimization

Whether used separately or in combination, Siemens PICVs and VFDs contribute to a high level of hydronic flow optimization:

- PICVs combine the functions of a control valve, automatic pressure regulator, and flow limiter ensuring the flow changes only when and where you want it to change, as well as simplifying the basic hydronic system.
- VFDs reduce pump speed to optimize flow and lower energy consumption.

Together they optimize hydronic flow, maximize energy savings and provide comfort throughout the building.

# » Siemens Resources

## Siemens technical expertise can help you optimize your hydronic systems

### Free sizing and selection tool, SimpleSelect™

Design tools save time and money.

SimpleSelect, a valve sizing and selection software tool from Siemens, simplifies time-consuming work by quickly and accurately sizing, selecting, and scheduling valves, actuators, and assemblies.



The SimpleSelect tool searches Siemens' entire valve and actuator portfolio and speedily finds the products you need.

An intuitive, easy-to-use interface helps you quickly size the valve you need with menus that allow you to:

- Select type of valve from the range
- Choose the medium being controlled
- Determine the correct Cv
- Calculate pressure drop and quantity of steam.

Download SimpleSelect onto your desktop today!

**Visit [usa.siemens.com/simpleselect](http://usa.siemens.com/simpleselect)**



# » *Siemens Resources*

**Go to the Siemens *Hydronic Flow optimization page* for more information about PICVs, VFDs, and hydronic balancing.**

Siemens can help you by providing the following links and resources:

- Information about PICVs
- Information about VFDs
- Information about hydronic balancing
- White Papers
- Link to the SimpleSelect valve sizing and selection tool
- Link to MasterSpec
- Siemens technical expertise sets its hydronic systems apart.

**For more information, contact Siemens Customer Service at (800) 877-7545.**