Understanding Variable Flow Systems

Part 3 of 3

By Amrish Chopra
Anergy Instruments Pvt. Ltd.
Faridabad

Figure 1 shows a typical Primary-constant/ Secondary-variable flow system. This system has one major disadvantage – of low ΔT; the return water temperature to chillers often falls below the design value.

Low ΔT across chillers could be for any of the following reasons:

- Forward flow in the decoupler bypass
- Excess water flow through AHU coils
- Inefficient heat transfer in AHU coils

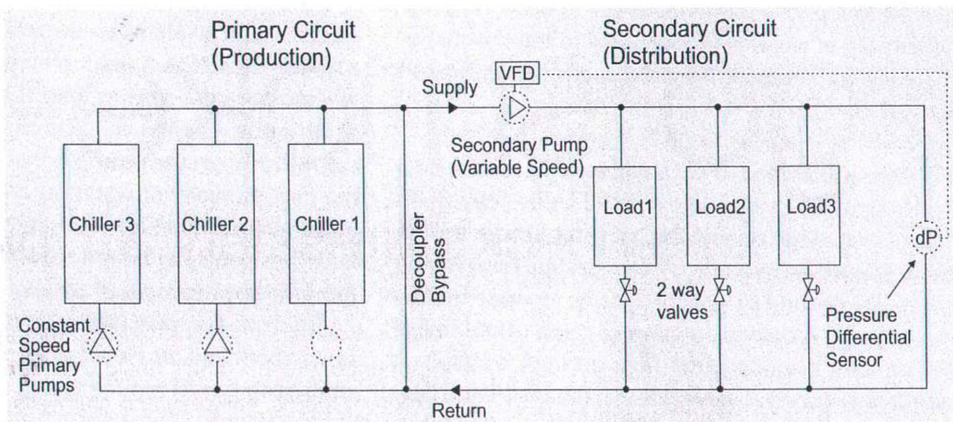

Figure 1: Primary-constant/secondary-variable flow chilled water system

Decoupler bypass is provided in the system to hydraulically isolate the primary and secondary circuits. It bypasses the excess water in any of the two circuits. A best practice would be to match the flow in the two circuits, but that is very difficult to achieve because HVAC load varies all the time whereas the chiller capacity can only be varied to a certain extent. To be able to service the load properly, the design chilled water temperature in the secondary supply header has to be maintained, and for that the operative chiller capacity has to be more than the instantaneous load. In such case excess water in the primary circuit flows through the decoupler bypass, from supply header to return header, mixes with return water of the secondary circuit, and lowers its temperature. Selecting chillers and primary pumps so as to be able to track the load closely can reduce the forward flow in the decoupler bypass.

Heat transfer capacity of a coil depends on many factors. Factors like heat exchange surface area, material conductivity, physical design, etc. may not change over time but other factors, listed below, may change. This would change the heat transfer characteristics of the coil.

- Air entering temperature
- Air velocity
- Dry or wet operation
- Water entering temperature
- Coil fouling on water and air side

The reasons for changes in these factors could be:

- Set-points are often lowered to resolve a comfort problem resulting in lower space temperature, and thus lower coil air entering temperature. To meet this demand, the controller forces the control valve to open more to allow higher water flow than the coil can effectively utilize, resulting in low outlet water temperature. Improper valve selection could also result in excessive water flow.
- Choking of filters could reduce air flow and, thus, air velocity, degrading heat transfer effectiveness.
- Lower plant capacity than the load causes a reverse flow in the decoupler bypass; return water mixes with supply water, raising its temperature. High supply water temperature may cause the coil to operate in the dry region, increasing coil bypass and thereby reducing coil heat transfer effectiveness.
- While in use, after some time the coil tubes on water side may accumulate slime or scale or may corrode, and fins on air side may get dirty or deteriorate, reducing heat transfer effectiveness.

A system with lower ΔT has higher flow rate for the same capacity, and increase in flow rate requires higher pumping power. In addition, lower inlet temperature than design reduces chiller capacity and increases power consumption per unit of heat output. Higher flow requirement in the secondary circuit sometimes may also necessitate running an additional chiller, further increasing energy consumption.

continued on page 82

continued from page 80

ΔT Override Control is the Solution

A simple solution to all the problems of low ΔT across the coil is to install two temperature sensors – one at the coil inlet and the other at the outlet – to measure ΔT and override the control valve in case ΔT drops below the design valve.

Generally the control valve operates under the dictates of the space sensor, but low ΔT means that the control valve is permitting more water through the coil than required for proper heat-exchange. ΔT sensors override the room sensor signal and close the valve, if required, to prevent a drop in ΔT. The point to be noted is that a space sensor operates the control valve to satisfy the load requirement whereas ΔT sensors allow only as much water through the coil as its instantaneous heat transfer capacity.

Heat capacity (H) of water is proportional to the product of water flow rate (Q) and temperature difference of entering and leaving water (ΔT).

$$H \propto Q \times \Delta T$$

A control valve is provided at each coil to regulate the flow to satisfy instantaneous load; it is expected to be fully open at full load. However, a full open valve may not ensure design flow; it may vary based on hydronic system design. Any change in the flow rate will change ΔT proportionally; increase in flow rate would reduce ΔT. A balancing valve or some other device may be used to limit the maximum flow through a circuit. A pressure independent control valve (PICV) has a maximum flow limiting feature built-in. It is achieved at the cost of rangeability, by reducing the operative stroke of the valve.

Limiting the maximum flow ensures design ΔT at full load, provided the coil is new and its heat transfer efficiency is as per design. However, after a while in use a coil does get fouled, its fins and tubes get dirty, and its heat transfer efficiency goes down. Then, even with maximum flow limit at full load, ΔT would fall below the design value.

At part load, this problem of low ΔT exists all the time. A control valve always has a tendency to open to achieve the space conditions as soon as possible. It permits more water to flow, carrying more heat than the coil can transfer, resulting in low ΔT.

Flow measurement and control is no solution for low ΔT problem, as it is unable to sense the coil heat transfer efficiency. ΔT override solution is simple, rugged and fool-proof. It uses two temperature sensors, one at the inlet and the other at the outlet of the cooling coil. A controller calculates ΔT across the coil. It works on the principle that any drop in ΔT indicates that the heat capacity of water entering the coil is more than the instantaneous heat transfer capacity of the coil and hence the flow rate needs to be reduced. It overrides the control signal from the space sensor to achieve this.

This solution may increase the time required to achieve the space conditions, but it is a small sacrifice in the larger interest of controlling low ΔT and improving overall plant efficiency.