# Out With the Old, In With the New

## Replacing PID control with demand-based control

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Last month, I discussed cost- and energy-related drawbacks of continuing to employ PID (proportional + integral + derivative) control in HVAC systems and introduced the concept of interdependent network control, which can replace PID control to improve the performance and efficiency of many systems. Interdependent control employs resource-management techniques similar to those used in information-technology networks. This month, I will provide a brief overview of a "demand-based-control" application to show how temperature- and pressure-setpoint control can be eliminated while the performance and efficiency of an all-variable-speed HVAC system are improved.

### ALL-VARIABLE-SPEED HVAC SYSTEMS

Applying variable-speed AC drives to HVAC components with built-in extra capacity saves energy at all expected load conditions. For this energy saving to be maximized, pressure differentials must change as the load conditions change. This is why temperature- and pressure-setpoint reset commonly is used as an optimization technique in conventional control systems.

### DEMAND-BASED CONTROL

Demand-based control is a network-enabled method of control that modulates equipment to meet current loading conditions and, at the same time, automatically optimizes overall system operation, thus eliminating the setpoint-optimization step. Demand-based control also reduces construction, energy, and operation-and-maintenance costs by simplifying system configurations, reducing pressure losses at all load conditions, and eliminating much of the wear and tear on modulating components.

Imagine designing the controls for a HVAC system in which all cooling-tower fans, condenser-water pumps, chillers, chilled-water distribution pumps, and supply fans employ electric variable-speed operation. Because of mechanical- and electrical-efficiency considerations, each of these components operates most efficiently within a capacity span that varies for each system element and may depend on more than a single operating parameter. Demand-based control recognizes that the operation of each piece of equipment influences the operation of every other piece of equipment in a system. In a demand-based-control system, network controls coordinate the operation of all equipment as a single system to meet all of the cooling loads effectively and efficiently.

**Demand-based control at the zone level.** Variable-air-volume (VAV) boxes in a demand-based-control system employ "cooling-effect" operation rather than just airflow control. Cooling effect is a combination of airflow and temperature effect and is calculated approximately once a minute in each VAV zone. The calculation considers airflow, supply-air temperature, and zone temperature. The cooling effect is compared to the deviation from the space-temperature setpoint in each zone, and a damper-position adjustment is made to increase or decrease the cooling effect as required in each zone. A self-balancing calculation also may be included so that the cooling-effect parameters for each zone are automatically adjusted. Each zone communicates certain information to the fan system serving it.

**Demand-based control at the fan-system level.** With demand-based control, a fan system can respond to changes in zone-cooling demand by adjusting the speed of the fan(s) and/or the flow of chilled water through the cooling coil. Supply-air temperature and pressure are not directly controlled, acting only as limiting values to ensure equipment operates within manufacturer and system design parameters. This approach offers a great advantage in meeting zone loads. If one or more zones is not obtaining adequate cooling effect, the system determines whether it would be more efficient to increase airflow or reduce air temperature. If the system chooses to reduce air temperature, it will slightly increase chilled-water flow to the air-handling-unit (AHU) cooling coil. VAV zones that already are satisfied will automatically reduce their airflow, resulting in both an increased air volume and lower-temperature air being immediately available to the zones that require additional cooling. Such control substantially improves system responsiveness and operating efficiency. The readjustment takes place about once a minute.

### CHILLED-WATER-DISTRIBUTION DESIGN

Adjusting chilled-water valves once a minute simplifies control and makes control stability much less of a problem than it is with PID control. The less-stringent incremental requirements of demand-based control afford designers an opportunity to improve efficiency.

Valves can be sized for lower pressure losses, as linear response to actuation is not required. Furthermore, with network-management techniques, there is no requirement that each valve operate independently of the others. Demand-based-control valve-selection rules call for a full flow pressure drop of 1 to 2 ft of head in worst-case configurations. The rules also require that some method of automatic coil-overflow protection be provided. This feature may be incorporated into the valve itself or the AHU controls. Simple ball or butterfly modulating valves work well in demand-based-control applications. Modulating valve actuators should be slow-acting. Although 120- to 300-sec actuators are

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ideal, faster-acting actuators will work fine as long as their total movement during each adjustment period is limited.

With demand-based control, there is no need to have identical pressure differentials at each load, so reverse return configurations are not necessary. Pipes should be sized to keep velocities and pressure losses within recommended limits, with some system analysis performed to select the distribution pump(s). Slightly oversizing the pumping capacity in a variable-speed system carries no energy penalty; however, to maintain good electrical efficiency at lower flows, pump motors should be sized as small as possible. Operating the pump motor into its service factor at peak conditions is what the factor is designed for. There is no concern about motor overload because the variable-frequency drive can automatically limit the power to its rated maximum.

**DISTRIBUTION-PUMP CONTROL**

There are several methods of applying demand-based control to chilled-water-distribution pumping systems. The one I prefer is the orifice-area method, by which pump speed is regulated according to the percentage of total valve orifice area opened. For ball and butterfly valves, fractional valve opening can be calculated by raising the fractional actuator position to a power of about 2.7. In single-pump systems, multiplying this fractional opening by the valve's full flow as a percentage of total-system maximum flow and summing the value for all valves is used to directly set pump speed as a percentage of the maximum speed when the pump is sized to meet full-flow requirements. The advantage of this technique is that it allows the pump to operate at its highest efficiency at all flows. Experience shows that making this valve-area calculation and using it to set pump speed once every minute works very well regardless of the size of the pump and distribution system. When multiple pumps are employed, it is not difficult to determine the optimum orifice area at which a pump should be added or subtracted and to incorporate these switching points into the pump control.

**ELIMINATION OF SETPOINTS**

With demand-based control, there is no direct temperature- or pressure-setpoint control at the fan or pumping system. This frees the system to respond to changes in cooling requirements with simple network-management techniques that automatically optimize the overall system efficiency.

When demand-based control is applied to fan systems and chillers, as well as to chilled-water distribution systems, it has the ability to drastically improve the comfort of buildings and cut total HVAC electricity use in half.

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