Network Based Control of Fluid Distribution Systems

by

Thomas Hartman, P.E.
The Hartman Company
www.hartmanco.com

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Introduction

I'd like to start by thanking the organizers for their hard work that has made this conference a success. I also thank you who are attending this session. As we continue to discuss the development of more environmentally friendly technologies to meet the responsibilities and challenges of the 21st Century, we are finding valuable opportunities to make a difference for all who depend us. I offer my encouragement and welcome to all who are committed to making such important differences!

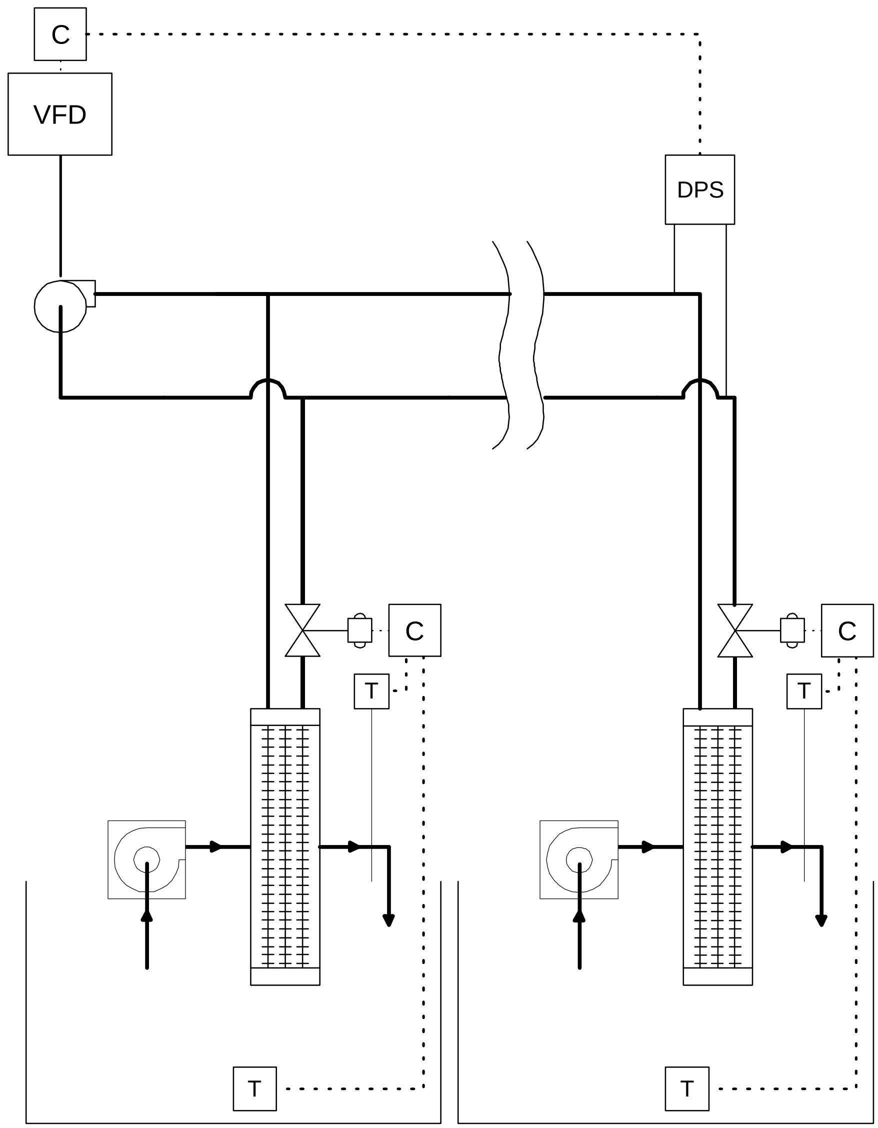
This afternoon, I will be discussing a new approach to operating variable flow pumping systems that serve multiple loads each equipped with its own modulating control valve. I will show how the inherent inefficiencies of current design practice can be mitigated by a new network based control approach to vastly improve the operating efficiency of such systems.

Background

Variable speed control of AC motors that operate distribution pumps has been available for more than a decade, and its use in variable flow water distribution systems is common practice. Such systems are regularly employed to distribute air for ventilation and cooling, and water from solar collectors or other heating sources for process or comfort heating. But nearly all variable speed flow control systems fail to achieve even a small portion of the theoretical improvement in operating efficiency at partial speed conditions that fan and pump laws show are possible. The problem is the use of outdated methods of control that hamper the effectiveness of this important technology by employing pressure based control which reduces the efficiency of a fan or pump as the flow requirements are reduced. The energy penalty for this type of control is substantial since an overwhelming amount of operating hours for many types of generating and distribution systems is spent at part load conditions where the benefits of improved distribution efficiency would add significantly to the overall system's economic viability.

Present Control of Variable Flow Water Systems

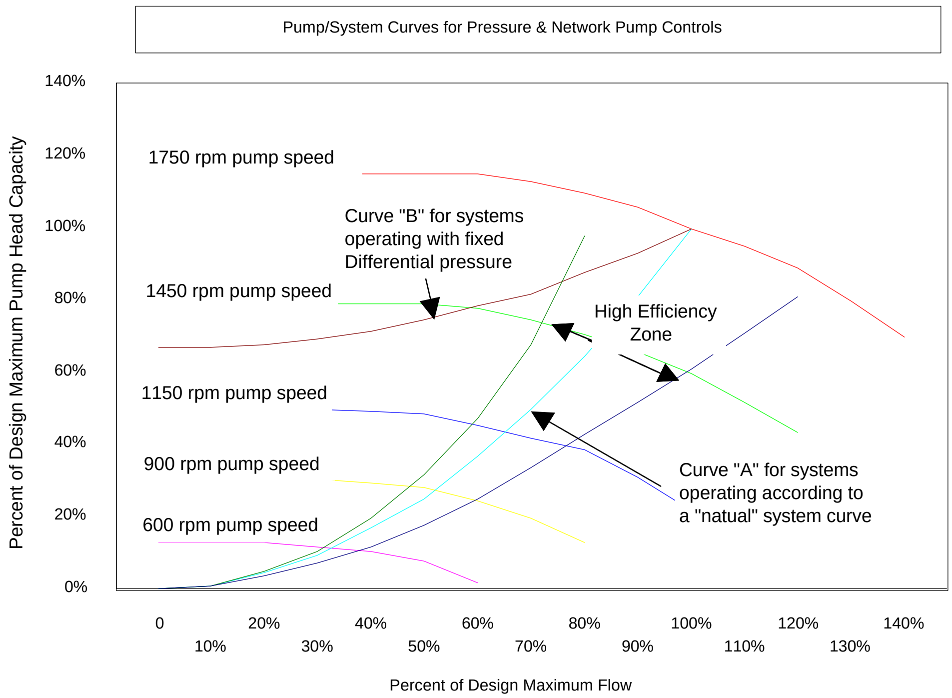
To illustrate the problems with current distribution control schemes, consider a variable flow chilled water pump serves multiple loads with modulating two way control valves as shown in the figure below:



Here, a variable speed pump is operated to maintain a differential pressure setpoint for a distribution system that serves a number of loads. Each load has a modulating valve operated by a DDC controller.

Pump and Fan Laws

Fan and pump laws dictate that a centrifugal pump can supply 50% of design flow at 50% speed and require only 12.5% (0.5^3) of the full flow power, but only if the pressure at which the fluid is supplied is permitted to fall to 25% (0.5^2) of the full flow pressure. If the supply pressure does not fall with the square of the flow requirements, then the pump speed cannot be reduced as the law allows. This results in a reduction in pump efficiency. These relationships are shown in the next figure.



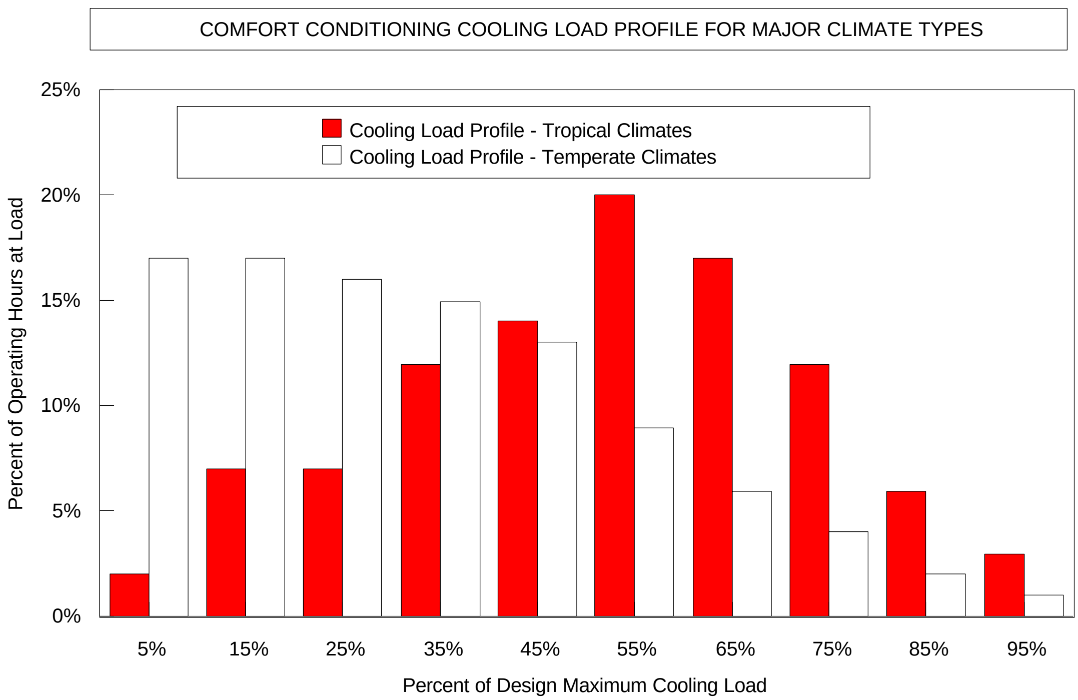
This figure shows the zone of highest pumping efficiency throughout the speed range of the pump. If the system can be designed such that the system curve falls within the “High Efficiency Zone,” (such the system curve is approximated by curve “A”), then the pump will operate at the highest pumping efficiency through all flows. However, as shown in the previous diagram, conventional distribution system designs operate to maintain a fixed differential pressure setpoint. The system curve for such variable flow distribution systems is represented by curve “B.” In these conventional systems, as flow requirements fall, pressure across the pump falls somewhat due to reduced pipe friction loss, but the reduction is limited by the differential pressure setpoint. For systems operating according to curve “B” the pumping efficiency quickly falls as flow requirements are reduced.

Part Load Operation

There are actually two costly energy penalties for systems that follow curve “B”. Loss of pump efficiency is one of them. The second is the high pump head pressure required at decreased loads. Because the majority of variable flow pumping systems are operated to maintain a fixed differential pressure between the supply and return distribution lines, the pumping pressure is not permitted to fall significantly as the load decreases, and a substantial energy penalty is the result. This combination of reduced pump efficiency and a higher head pressure limits pump power reduction opportunities at part loads.

Because pumps are simple devices that are very efficient at their sweet spots (the high efficiency zone in the above figure), it is reasonable to try to find ways to accommodate their limitations and develop system concepts that permit the pressure to fall as flow decreases in order to operate them at the highest possible efficiencies throughout all flow conditions.

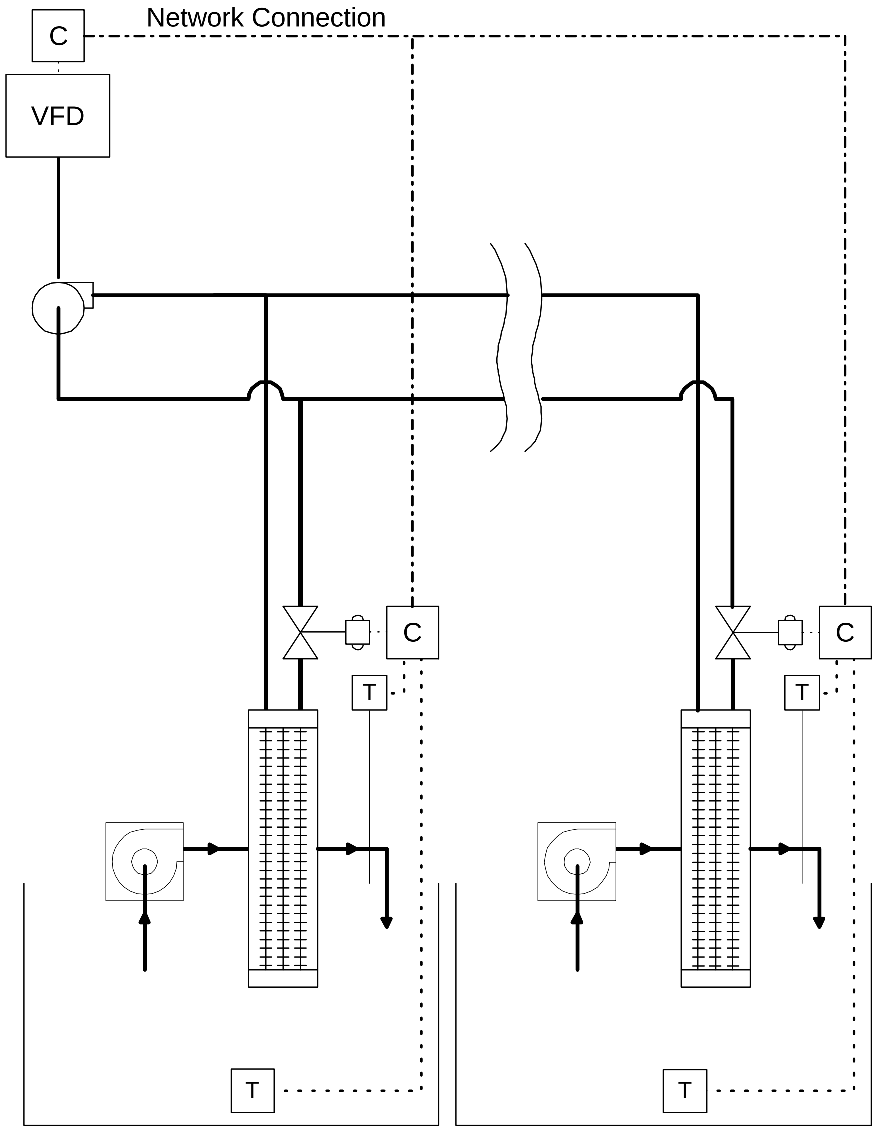
The value of such an approach is illustrated by the figure below which shows the expected load profiles for chilled water plants employed for comfort conditioning.



This figure shows the percent of total operating hours the system spends at various load capacities for each of the two basic world wide climates - tropical climates (the solid bars) and temperate climates (the hollow bars). Assuming the chilled water flow is proportional to the load, the above figure also provides a good indication of the flow requirements for a distribution system serving such loads. Note that the overwhelming majority of pumping hours are spent at reduced flows in both climate types. Systems operating according to Curve “A” in the previous figure can achieve enormous energy savings over curve “B” systems at these part load flow conditions.

A New Efficient Approach

To improve the efficiency of such chilled and heating water distribution systems, a new network based technology has been developed that links the operation of the variable speed pump directly to the loads it serves, rather than employing a differential pressure to operate the pump speed. A diagram of this configuration is shown below:



Notice the similarity of this configuration with current conventional design. All that is different is that the differential pressure sensor has been eliminated and a control network added such that the controller operating the pump and each of the controllers operating the valves served by the pump are linked by that network connection. This approach allows the pump to slow so long as all the loads are satisfied, without regard to a differential pressure, improving the energy efficiency significantly.

Benefits of New Network Pump Controls

By employing network pump control, the pump can adjust its speed at all times to meet the actual flow requirements of each load served. This means that there is a reduced potential for any of the loads to suffer inadequate flow, a potential problem when only pressure control is employed. In addition, the configuration of a network pump control system is simpler because the differential pressure sensor is eliminated.

However, the most important benefit network pump control provides in substantially lower pumping energy costs. Network pump control reduces energy two ways. First, it keeps the pump operating at higher efficiency throughout its flow range, and second, it allows the pump to operate at lower pressure during most part load conditions. The actual amount of energy saved by the replacement of conventional pump control with network pump control depends on the size and pressure characteristics of the system, as well as the type of pumping and load profile. However, in most applications, replacing conventional pumping with network pump control will reduce annual pumping energy use by well over 50%.