

Pump System Controllers for Leakage Management

Discusses utilization of flow-controlled pump stations as a method to reduce distribution system leakage and reduce power costs

The purpose of this paper is to discuss utilization of flow-controlled pump stations as a method to reduce distribution system leakage and, as an additional benefit, reduce power costs associated with the more traditional constant pressure systems. Though conceptual, this article discusses in general terms pump station controllers that are being used to track the varying pressure requirements in distributions systems. By anticipating those requirements based upon flow, modern day pumping systems controllers can provide smooth-flow systems that meet the minimum pressure requirements.

- Steven L. Frasure

Introduction

Millions of tax dollars are being spent to treat water to ensure it is safe for human consumption. Millions more are being spent to distribute the same water to our homes, schools, hospitals, and businesses. In the meantime, millions of gallons of that valuable treated water are lost to leakage due to excess pressure.

New technology has opened doors for new and more efficient methods for controlling the distribution of water. There are thousands and thousands of miles of piped distribution systems today filled with moving water that can be saved from leakage due to excess pressure.

Considering the age of the nation's piping systems and the massive area covered, it is virtually impossible to prevent all leakage. Providing minimum water pressure at all connection points throughout the day is essential to the process of providing water to consumers.

But how much pressure is too much and how much is not enough?

Flow requirements change throughout the day which causes the pressure requirement to change. The traditional solution is to over pressurize just in case. Excess system pressure is the prime cause, yet the often ignored leakage problem.

There have been many discussions regarding solutions to reduce leakage. One such method is reducing distribution system pressure set points during off-peak demand periods. Another proven method is installing pressure regulating valve in metered zones to minimize excess pressure during low flow periods.

It is accepted that controlling the discharge pressure of pumping stations will substantially reduce leakage. Beyond that, new technology permits controlling the pump station pressure so as to match the actual demand. In other words, consumers get what they need—nothing more and nothing less.

Though not an expert on distribution system design or causes of distribution leaks, the layperson can appreciate the fact that pipes with holes do not hold water as effectively as pipes without holes. Furthermore, applying pressure to water pipes with holes will increase the amount of water running out the holes. Increase the amount of pressure and the flow will also increase.

It is accepted that as pressure increases the amount of leakage increases. It is also accepted that water leakage can account for 10% to over 40% of the total supply volume. A one-million-gallon per day system could be losing over 400,000 gpd to leakage. Put into perspective, a 1/16" leak in a pipe will lose over 100 gpd.

Taking into account costs associated with leakage and excess power consumption, many experts are working on ways to control this problem. The current objective is to minimize excess pressure, thereby reducing leakage.

Typical distribution system criteria

Using an example of a typical distribution system, this article examines the relationship between flow demand and pressure at the critical point in the system. There are many actions that can be taken to reduce pipeline leakage. This article, however, will only focus on controlling the pump station discharge pressure.

The system's flow rate is 290,000 gpd. It should be noted that this example does not include an elevated storage tank integral to the system. The topography is relatively flat and the pipe is ductile iron and approximately 15 years old. Consumers consist of mostly mid-sized homes, schools, a hospital, and small businesses. The pump station inlet or suction pressure is 40 PSIG and fluctuates no more than 10 PSIG up or down. The discharge pressure is regulated by pressure regulating valves on each pump discharge, which maintain a constant 83 PSIG. The minimum acceptable pressure at the critical point is 43 PSIG. The example pump station consists of two ten-horsepower main pumps and one 7.5 horsepower lead pump, estimated to be 65% efficient.

In the typical distribution system, beginning at midnight, the flow is low and stays low until approximately 4:00 AM. In the following two-hour period the flow increases to maximum demand at 6:00 A.M. From 6:00 A.M. to approximately 5:00 P.M., the flow drops again. After 5:00 P.M. flow increases to the second highest demand at approximately 8:00 P.M. After 8:00 P.M. the flow rate drops to the lowest rate occurring just before midnight.

At that point the cycle begins again.

Time-based pressure control for leakage management

There are specific times during the day where the demand and pressure requirements are relatively lower and constant. It is important to note, however, that during the low-flow periods the pressure provided is much greater than required to meet the minimum at the critical point.

Blocks of time shown on the graph represent periods of time the pump station pressure could be reduced to without the risk of the pressure dropping below the minimum acceptable level.

By reducing the pump system discharge pressure the distribution system becomes more efficient by reducing excess pressure. The result is less leakage and lower power costs.

This is accomplished by utilizing a programmable logic controller (PLC) as the pump system controller. It determines the time of day and the current flow rate, then communicates the appropriate pump speed to the variable frequency drive, increasing or decreasing the speed to coordinate the pressure to the flow demand to maintain the desired pressure at the critical point.

Environmental and economic impact

In this analysis, the leakage rate was assumed to be very low and conservative. The total leakage rate was estimated to be 551,880 gallons per year, which is only 1% of the annual system flow rate of over 106 million gallons. Most experts believe the leak rate for older systems to be in the 10% range. The leakage rate attributed to excess pressure was estimated to be 374,928 gallons per year. Power cost savings directly attributed to excess pressure are estimated to be \$3,909 per year, based upon 10 cents per kilowatt-hour.

Based upon constant system pressure of 83 PSIG the power cost was \$9,667. Utilizing time-based pressure control the power savings were \$3,909.

Concept of flow-controlled pump stations for leakage management

Controlling the pressure of a pump station is common practice. In most cases this means maintaining a constant pressure utilizing pressure regulating valves (PRV) or variable frequency drives (VFD). The PRV is a mechanical device that primarily creates a friction loss in the system similar to opening or closing a valve and is a proven method for pressure control. Set the desired system pressure and the valve modulates closed or open to maintain a constant discharge pressure. With the cost of variable frequency drives dropping over the years, coupled with better reliability, VFDs have become popular. Relying on the input signal of a system pressure transducer, the VFD can slow down or speed up in

order to maintain constant pressure. Both PRVs and VFD are proven methods of pressure control that accomplish the same objective.

The most recent improvement in technology is controlling the discharge pressure of pump stations based upon not only the pressure but also the flow.

In this case, the pump station discharge pressure can virtually match that which has been preset to the corresponding flow; such as in the time-based example where set points are predetermined and programmed based upon time of day. Adding an accurate flow rate to the application, the pump station programmable computer can evaluate the flow, pressure and the time of day. The PLC will then determine the most efficient pressure for the station, then adjust the VFD speed to match that requirement. This applies only to friction loss and has minimal benefit for high static head applications with low friction loss.

In pumping applications for most municipal distribution systems it is common for the friction head loss to be greater than 10 PSIG or 23 ft dynamic head. In this case, most systems would benefit by reducing the pumping station discharge pressure based upon time or demand or both.

Summary and conclusions

The correlation between leakage reduction and system pressure management is obvious. Reducing excess pressure in a distribution system will save water and power costs. The best method for controlling pressure, on the other hand, is less obvious because of the many factors to be considered.

It is clear to plant operators and system designers that in most cases systems have excess pressure during certain times of the day. It is an accepted downside so as to insure adequate pressure all the time. The new developments in variable frequency drive controls that were proven in other industries show great promise for the potable water distribution systems. Pump system controllers, responding to distribution system conditions, offer a pragmatic solution to the expensive problem of excess pressure leakage.

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