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Implementing Mid Ranging in a DCS Environment

Dr. Nicholas Alsop*

*Senior Process Control Engineer, Borealis AB, Stenungsund, Sweden
(Tel: +46 303 870 75; e-mail: nicholas.alsop@borealisgroup.com).

Abstract: Mid ranging is an algorithm for controlling one control variable, such as flow or pressure, with two manipulated variables. Although mid ranging is a very well established technique there are a number of practical issues which must be addressed when implementing mid ranging in the DCS. These issues include handicapped operation, bump less transfer and proper handling of saturation conditions. In this article, an algorithm for mid ranging is presented which exploits the inbuilt functionality of the control blocks in a modern DCS. A specific feature of the algorithm is the ability to maintain control even when one of the manipulated variables is out of service. Finally the article also demonstrates how the algorithm is extended to handle three manipulated variables.

Keywords: Mid ranging, Distributed Control System, Integral Control, External Reset Feedback.

1. INTRODUCTION

Mid ranging is an algorithm in which two control handles are manipulated to control one control variable. The most common process application for mid ranging is when flow or pressure is controlled using two valves of different size situated in parallel.

Typically, control valves with high flow capacity have poor control characteristics at the extremities of the control range. To circumvent this problem, a small valve with favourable flow characteristics at low flows is installed in parallel with the large valve. The purpose of mid ranging control is to coordinate the actions of the small and large valves to achieve fine control of flow over a wide range.

One of the most common examples of the parallel valve configuration is pressure control of fuel gas in fired furnaces. When the furnace is on standby, highly accurate pressure control of fuel gas is required to achieve the correct firing conditions in the burners. This can only be achieved using a small control valve. At normal firing loads the larger valve is required to accommodate the much higher fuel demand.

Several solutions to the mid ranging control problem have been reported in the academic literature including valve position control (VPC), hybrid control and model predictive control (MPC). VPC is the most popular strategy on the basis of simplicity and ease of implementation. However the VPC is recognised to be difficult to tune and can yield suboptimal control in the presence of saturation. Tuning methods for VPC based on internal model control (IMC) principles have been proposed in Allison and Isaksson (1998) and Gayadeen and Heath (2009) and alternative anti windup strategies are described in Gayadeen and Heath (2009) and Haugwitz (2007).

The MPC solution for mid ranging control is shown in Allison and Ogawa (2003) to give superior performance over the other methods in the presence of saturation, or when the process dynamics are complex. MPC is also ideally suited to handling the handicapped mode of operation in which one of the control valves is out of service. However, it is noted that due to the cost and complexity of installing MPC, it is unlikely that this technology can be justified for mid ranging control unless it forms part of a wider control strategy.

In the last section of this report, an algorithm for mid ranging based on the sliding split range concept is described. This algorithm is similar to the hybrid algorithm described in Allison and Isaksson (1998), with the distinguishing feature that it exploits the built in functionality of the DCS to deal with the issues of handicapped operation, bump-less transfer and saturation. The algorithm thereby avoids the complexity of transfer function based solutions from the literature which can become complex and difficult to maintain when logic for mode switching, initialisation and windup propagation is imposed.

2. CONTROL USING TWO PARALLEL VALVES

The simplest control scheme for the two parallel valve configuration is two separate controllers as illustrated in Figure 1. In this example from a fired furnace at a Borealis cracker plant, pressure controller PC1 controls the flow through the small line only, and PC2 controls the large flow.

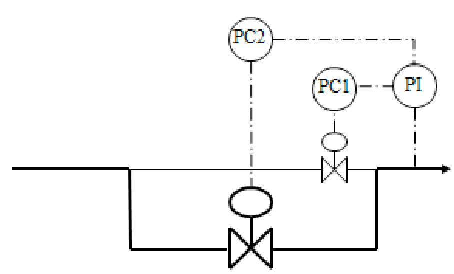

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Figure 1 Pressure Control using Separate PCs

Control of parallel valves using two separate controllers generally works well when the operating window can be divided into two distinct ranges. In this case only one of the flow controllers is needed at any one time, and the other can simply be placed in MAN mode and fully closed.

The major pitfall of the two controller scheme is observed in the transition region. In this region a flow is required which is near the maximum capacity of the small valve. To achieve the desired flow the operator must juggle the setpoints and modes of both the PCs.

Automatic transitioning between the small and large valve ranges can be achieved using a conventional split range strategy as illustrated in Figure 2. The split range strategy works by dividing the output from the main controller into two valve signals as defined by a split range profile as shown in Figure 3.

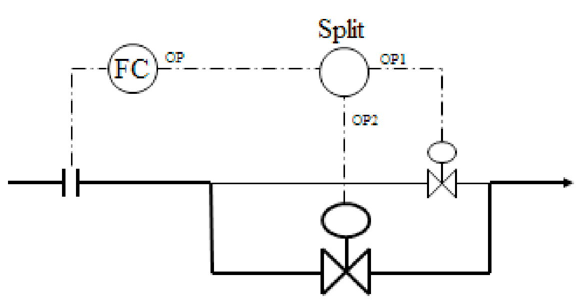

Figure 2 Split Range Flow Control

The breakpoint in the split range profile is placed in order to achieve a linear flow characteristic over the whole OP range. In this example, the capacity of the large valve is 4 times greater than the small valve, which is why the breakpoint is placed at 20%.

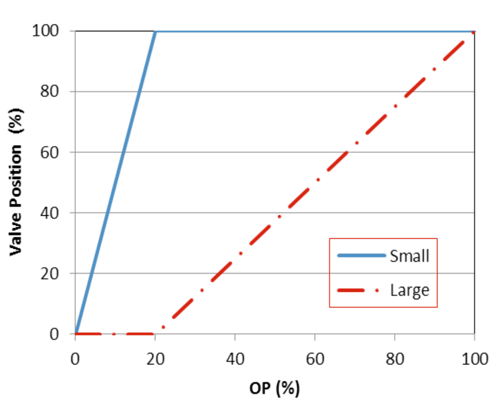

Figure 3 Split Range Profile

In practice, the split range scheme exhibits poor control in the transition region because the large valve often has poor flow characteristics when it is barely open. A sporadic and/or highly non-linear flow response of the large valve in this regime makes fine control of flow impossible.

The handicapped mode of operation, in which one of the valves is in MAN mode, and the 3 valve configuration can also be accommodated in both schemes.

3. MID RANGING CONTROL

The purpose of mid ranging is to provide achieve good flow control over the range of capacity for the two parallel valves. The underlying principle is that fine continuous control is done by quick movements of the small valve while the bulk flow is accommodated by slow positioning of the large valve. The 2 valves are orchestrated to the tasks they do best. It can also be argued that the mid ranging algorithm reduces overall maintenance costs by minimising the accumulated travel of the large valve

The steady state behaviour of the mid ranging algorithm is illustrated in Figure 4. The key feature of the algorithm is that only the small valve is used at the extremities of the flow range. As the small valve is in the middle of its control range when the large valve begins to open, it is capable of compensating for the sporadic and/or non-linear flow characteristic of the large valve. In the middle of the flow range, the small valve converges to the middle of its control range, and the flow demand is met by the large valve.

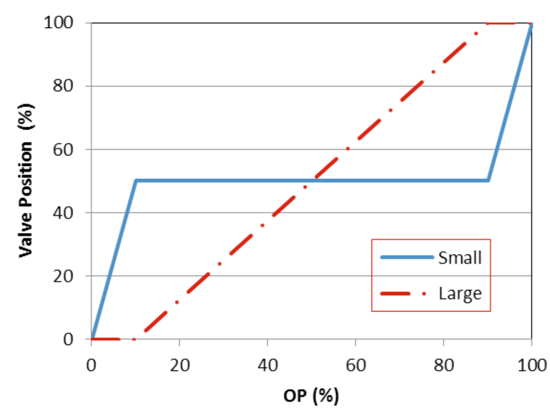

Figure 4 Steady State Characteristic for Mid Ranging

The dynamics of the mid ranging scheme are illustrated in Figure 5. In this simulation, a load change from 20% to 25% (blue trend) causes a quick corrective move of the small valve (yellow trend) from 50% to 75%, after which it retreats back to 50%. In the meantime the big valve (purple trend) moves slowly from 12.5% to the new steady state at 18.75% as required.