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Application Note

Control Strategy: Ratio Control Systems

Abstract

Ratio control systems are installed to maintain the relationship between two variables to control a third variable. Ratio control systems actually are the most elementary form of feedforward control. The system load is called the wild flow and it may be uncontrolled, controlled independently or controlled by another controller that responds to variables of pressure, level, etc. Ratio control is applied almost exclusively to flows, and there are correct and incorrect methods of implementation, both of which will be addressed.

Introduction

This Application Note will address both the correct and incorrect implementation of ratio where the ratio calculation is made outside the loop, and the incorrect implementation where the calculation is made inside the loop. Also presented is the proper sequence for applying the *Protuner System Analyzer* to test and optimize the system installed dynamic operation.

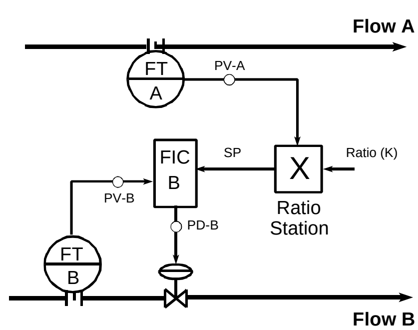

Figure 1—Ratio calculation of controlled flow B to wild flow A outside closed loop

Correct Implementation of Ratio Control

Consider in this first example, a control system designed to maintain a certain ratio R of ingredient B and ingredient A:

$$R = \frac{B}{A}$$

The more common and correct way to accomplish this means manipulating the setpoint of the flow controller controlling the flow of ingredient B (controlled flow) as a function of the desired ratio and the measured flow of ingredient A (wild flow). The setpoint of flow controller B is calculated:

$$B = RA$$

Figure 1 illustrates such a system. In this example, the ratio of the two ingredients is maintained by adjusting the setpoint of the flow controller FIC-B, using an adjustable gain device known as a ratio station. The input to the ratio station is the measurement of the wild flow A, which is multiplied by a constant. The output of the ratio station is then the setpoint to FIC-B to maintain the desired ratio for the two ingredients.

Since the ratio calculation is done outside the control loop, it does not interfere with the loop response.

Protuner Analysis of the Installed System

The only feedback controller in the system is the controlled flow B. To tune controller FIC-B connect the *Protuner* to measure the input to the controller PV-B and the output of the controller PD-B. Place FIC-B in manual and record a series of step changes in the controller output and the corresponding response of the flow PV-B, in accordance with the *Protuner* test procedure for self-regulating processes documented in the *Protuner Applications Manual*. Use the *Protuner* to analyze the test results, to troubleshoot the loop, and determine the tuning parameters for FIC-B. Enter the tuning parameters from the *Loop Analysis Screen* for response to setpoint into FIC-B and place the loop back in automatic control. Control system tuning requires tuning the flow control loop for response to setpoint changes.

To insure proper operation of the system, additional testing should be done to insure that flow controller FIC-B can follow the changing setpoint from the ratio station. Problems can occur when the wild flow A is changing at a frequency in which no matter how well FIC-B is tuned, it cannot follow the changes in setpoint. The wild flow A, which is the load in the ratio control system, may be controlled independently or manipulated by another controller that responds to other variables such as level, pressure, etc. Often, the cause of the cycling found in flow A is caused by control problems in these other loops. Therefore, to optimize the system, these other loops will need to be identified, tested and optimized.

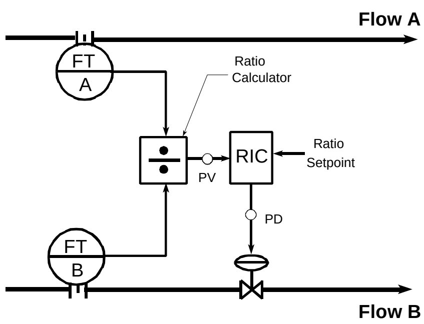

Figure 2—Flow ratio divider placed inside closed loop

Incorrect Implementation of Ratio Control

A second method to calculate the ratio R uses the individual flow measurements A and B. The calculated ratio then becomes the process variable measurement to the ratio controller with a manual setpoint. Changes to the setpoint of the ratio controller RIC would then change the ratio. ***Figure 2*** illustrates such a configuration.

The principle disadvantage of this system is that it places a divider inside the closed loop. If flow B responds linearly with flow valve B, the process gain of the loop will vary because of the divider. The following differential equation explains why this is true:

$$\frac{dR}{dB} = \frac{1}{A} = \frac{R}{B}$$

The process gain varies with the ratio and with flow B. In some cases, the ratio would not be subject to change, but the process gain of the RIC ratio control loop varies inversely with flow B. For conditions of low flow then, the process gain of the RIC loop would be high and, at high flow, the process gain would be low. If RIC were tuned to provide good response for low flow conditions, the loop response at high flow conditions would be very sluggish. On the other hand, if RIC was tuned for good closed loop response at high load conditions, the loop would be unstable at low load conditions. If the ratio was inverted,

$$R = \frac{A}{B}$$

then

$$\frac{dR}{dB} = -\frac{A}{B^2} = -\frac{R}{B}$$

and the results are essentially the same.

The only advantage of using the ratio computing form of implementing a ratio control system is that the controlled variable (flow ratio), is constant, and can be recorded to verify control. In the correct implementation illustrated in ***Figure 1*** the two flows would have to be compared for verification. This is a very poor reason to take what is an essentially simple linear process and configure the control system as a highly nonlinear process with major control problems. In short, the ratio control configuration shown in ***Figure 2*** is incorrect and should be changed if encountered in the field.

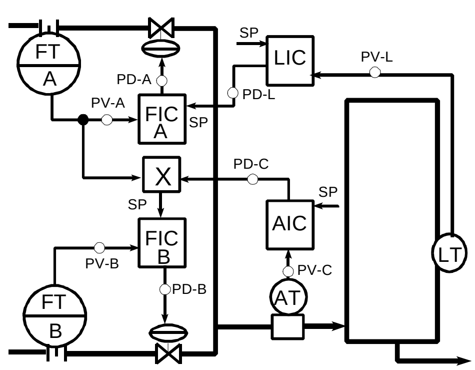

Figure 3—Level controller manipulates flow and composition controller manipulates ratio

Cascade Ratio Control

This example illustrates two combinations of cascade and ratio control to illustrate both the design of more complex ratio control systems, and the proper use of the *Protuner* for analyzing the control system dynamics. ***Figure 3*** illustrates a control system where a level controller manipulates the wild flow and a composition controller manipulates the flow ratio.

In this system, the two flows A and B, are mixed to control a precise composition of the combined flow C feeding into a storage vessel, used as feed to another process. Liquid level in the tank is affected by total flow, hence the level controller LIC sets the setpoint of the wild flow controller FIC-A, which in turn sets the setpoint of the controlled flow controller FIC-B proportionately.

Composition on the other hand is not affected by absolute value of either flow, but only by their ratio. Therefore, to make a change in composition (ratio), the composition controller AIC adjusts the multiplier of the ratio station.

Analysis Test Procedure for Installed System

The first step in the analysis of the system is to be sure the proper flows are chosen as the wild flow and the controlled flow. To minimize the effect of composition control on the liquid level control—through its proportional manipulation of flow B—flow B should be the smaller of the two streams.

The second step is to connect the *Protuner* to PD-B and PV-B to record the input and output of flow controller FIC-B. With the *Protuner* connected, record an open loop analysis test to determine the tuning parameters for FIC-B. Enter the parameters into the controller and place the loop in automatic. The next loop to test is FIC-A. Connect the *Protuner* to record PV-A and PD-A, then test the loop to determine the tuning parameters for FIC-A. Enter the parameters into the controller and place the loop in automatic.

With the two flow loops in automatic, the next step is to optimize operation of the composition controller AIC. Connect the *Protuner* to record the input and output of the composition controller (PVC), the composition measurement signal and PDC the ratio station multiplier. With AIC in manual, record a series of step changes in PDC, and the corresponding response of PVC, following the proper testing procedure for testing self-regulating processes. Analysis of the test results will determine the tuning parameters for entry to AIC.

The last loop to test in this example, is the level control loop LIC. Connect the *Protuner* to measure PVL, the process variable level measurement and the output PDL of the level controller, which is the remote setpoint to FIC-A. The open loop test procedure requires that the loop first be stabilized in automatic control to balance the system. Then, place LIC in manual and record a series of step changes in PDL, and the response of the level measurement PVL, in accordance with the test procedure for analysis of integrating processes. Analyze the test results to determine the tuning parameters for LIC.

Conclusion

In each of the examples, the flow measurements need to be linear for the installed system to be linear. Using head type meters without square root extractors will result in very nonlinear control problems, which can and should be avoided. It should also be clear, that there are correct and incorrect ways of implementing ratio control. The correct implementation where the ratio calculation is made outside the loop, and the incorrect configuration where the ratio calculation is made inside the loop. Unfortunately, the incorrect configuration is all to commonly found in the field. When this type of configuration is encountered, a lot of time can be wasted in designing special nonlinear controllers which will never provide the best control. The easiest solution, by far, is to reconfigure the loop to place the ratio calculation outside the closed loop.

No matter how the ratio control is brought about, a computing device must be used whose scaling requires some consideration. This area has not been covered in this presentation but needs to be addressed in the proper setup of any ratio control system. In pneumatic and analog control systems, the scaling is often a problem. In modern digital systems, however, most controllers can easily be configured for ratio operation.