# Multivariable Control

PART V

In this part we continue the trend of addressing increasingly more complex process control systems. Although some of the control systems in Part IV involved more than one measured variable, we considered these to be single-variable control because they had the ultimate objective of maintaining only one variable near its set point. By contrast, *multivariable control* involves the objective of maintaining several controlled variables at independent set points.

The simple chemical reactor process shown in Figure V.1 is considered first to introduce the concept of a multivariable process. The control objectives depend on the goals of the entire plant and of the design of associated equipment, but typical objectives would be to control the level, temperature, and outlet concentration at independent set points, which would be achieved by adjusting selected manipulated variables in the process. Again, the variability of the controlled variables is reduced through actions that increase the variability of the manipulated variables. In Part V the complexity of multivariable systems is reduced by assuming (for the most part) that the process design, measurements, and final elements cannot be changed; thus, the process dynamics and control calculations are addressed. These restrictions will be relieved in Part VI, when process control design is addressed.

Control of multivariable systems requires more complex analysis than that of single-variable systems, as summarized in Table V.1. Fortunately, essentially all methods and results learned for single-variable systems are applicable to multivariable systems. Thus, aspects of a single-variable system that make it easy or difficult to control have generally the same effect for multivariable systems. However, in multivariable systems new characteristics due to *interaction* must be

**TABLE V.1**
**Characteristics of multivariable control systems**

| Single-loop characteristics that generally lead to good control performance in multivariable systems | Characteristics unique to multivariable systems |
|---|---|
| 1. Fast feedback processes (small $\theta + \tau$) | 1. Interaction between variables influences control stability and performance. |
| 2. Feedback processes with a small fraction dead time ($\theta/(\theta + \tau)$) and no inverse response | 2. Feasibility of control depends on overall process, not just individual cause-effect relationships. |
| 3. Disturbances with small magnitudes far from the critical frequency | 3. The source of the disturbance, not just the magnitude, must be considered in designing the control strategy. |
| 4. No limitations encountered in the manipulated variable | 4. The pairing of measured variables and final elements via control is a design decision. |
| 5. Digital controllers with relatively fast execution periods | 5. Some processes have an unequal number of controlled and manipulated variables. |
| 6. Controllers based on accurate models | 6. Some multivariable control designs are very sensitive to modelling errors. |
| 7. Controllers using appropriate enhancements from Part IV | |

considered. Interaction results from process relationships that cause a manipulated variable to affect more than one controlled variable. In Figure V.1 the heating oil valve position influences both the temperature and, through the reaction rate constant, the concentration. This is the major difference from single-loop systems and has a profound effect on the steady-state and dynamic behavior of a multivariable system.

Thus, it is not possible to analyze each manipulated–controlled variable connection individually to determine its performance; the integrated control system must be considered simultaneously. A closely related new issue is the disturbance source, because multivariable systems respond differently to different disturbances. For example, the chemical reactor responds differently to disturbances in feed composition and feed temperature, and, as we shall see, these differences must be considered in designing a multivariable control system.

Another realistic issue is the number of controlled and manipulated variables, which may not be equal. Note that the system in Figure V.1 has four manipulated variables, which can be adjusted to control three measured variables. Multivariable control methods presented in this part are able to utilize all flexibility available in the process.

There are two basic multivariable control approaches. The first is a straightforward extension of single-loop control to many controlled variables in a process, as shown in Figure V.2. This is termed *multiloop* control and has been applied with success for many decades. The second main category is *coordinated* or *centralized* control, in which a single control algorithm uses all measurements to calculate all manipulated variables simultaneously, as shown in Figure V.3. Algorithms for this approach have been available for several decades and have been widely applied for a considerable time in the process industries.



At the conclusion of this part, the unique characteristics of multivariable process systems and how these characteristics affect process control will have been presented. The reader is cautioned that this is a complex topic, worthy of an entire book, and that the presentation here is introductory. However, it presents the major issues, along with some of the more common analysis methods and control approaches.

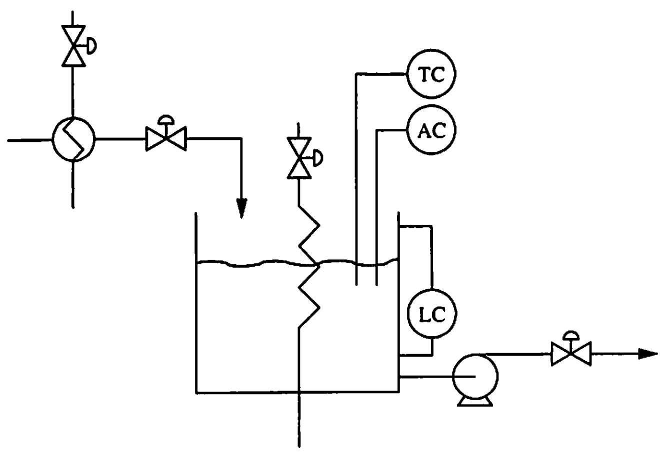


**FIGURE V.1**

**Multivariable process.**

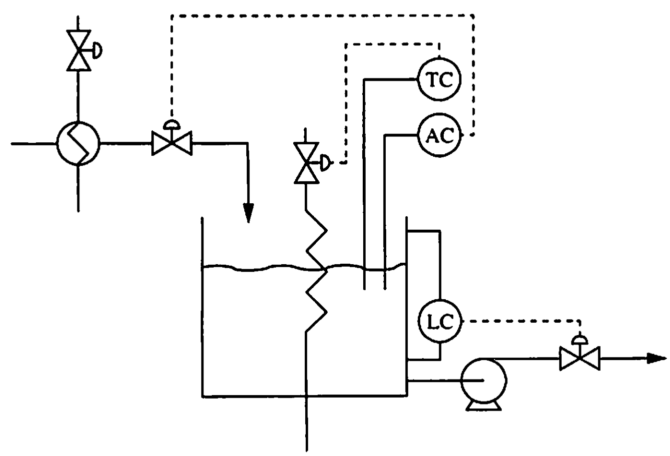


**FIGURE V.2**

**Example of multiloop control design.**

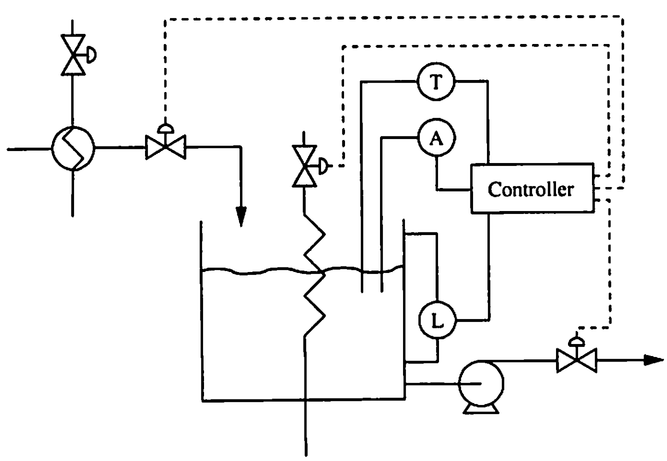


**FIGURE V.3**

**Example of multivariable control design.**