



INTRODUCTION

The term *process control* implies that there is a *process* for which there is a desired behavior and that there is some *controlling function* that acts to elicit that desired behavior. This broad concept can embrace everything from societal processes governed by some regulatory control authority to automated manufacturing processes. In practically all cases, however, a common thread is that some measure of the actual process behavior is compared with the desired process behavior. This feedback action then generates a control policy that acts to minimize or eliminate the deviation between desired and actual behavior.

We are concerned in this book with a particular segment of automated process control—that which is applied to chemical, refining, pulp and paper, power generation, and similar types of processes. Even within this limited scope of applications, we will limit the discussion primarily to processes that are operated continuously for long periods of time and within a narrow region of the operating variables. In other words, we exclude such important operating modes as batch processing, start-ups, and grade changes. Many of the control techniques to be presented here, however, can be adapted to these other modes of operation.

For the processes we focus on in this book, the process's behavior is often characterized by measured values of such process variables as temperatures, flow rates, pressures, and the like. The desired behavior, then, is stated to be the set points of those process variables. Until fairly recent times, most applications of industrial process control used simple feedback controllers that regulated the flows, temperatures, and pressures. These controllers required a form of adjustment called *tuning* to match their controlling action to the unique requirements of individual processes. Occasionally, more advanced forms of control, such as ratio and cascade, could be found; even more rarely one might find a feedforward control loop. As long as most of the control systems were implemented with analog hardware, applications were limited to simple regulatory control. This was due to the cost of additional components, the additional interconnections more advanced control required, the burden of maintenance, and the vulnerability to failure of many devices in the control loop. With the advent of digital control systems, however, more sophisticated loops became feasible. Advanced regulatory control—which includes the previously mentioned ratio, cascade, and feedforward control as well as additional forms such as constraint (selector) control and decoupling—could readily be implemented simply by configuring software function blocks.

With this additional capability, however, a need developed for a systematic approach toward using it. This is called *control strategy design*. In order to design a technically successful and

economically viable control strategy, the control system engineer must be well grounded in the techniques of feedback control as well as the tools of advanced regulatory control. The requisite knowledge includes both how to implement and how to tune. Even before that, however, the control system engineer must be adept at recognizing when to use (and conversely, when not to use) certain control methods as well as in projecting the expected benefits.

Using advanced regulatory control provides many benefits. One of the most important is simply closer control of the process. It will become very clear later in this book that with basic regulatory (i.e., feedback) control, there must be a deviation from set point before control action can occur. We will call this the “feedback penalty.” The objective of advanced regulatory control is for the control action to be taken by incurring only a minimal feedback penalty. The reduction in feedback penalty may be stated in a variety of ways, such as a reduction of the maximum deviation from set point, as a reduction of the standard deviation, or simply as a reduction in the amount of off-spec product produced. This reduction in feedback penalty can provide several forms of economic benefit, such as improvement in product quality, energy savings, increased throughput, or longer equipment life.

Process control is but one part of an overall control hierarchy. It extends downward to safety controls and other directly connected process devices and upward to encompass optimization and even higher levels of business management, such as scheduling, inventory, and asset management (see Figure 1-1). Indeed, corporate profitability may be enhanced more significantly as a result of these higher-level activities than from improved process control *per se*. However, since each layer of the hierarchy depends upon the proper functioning of the layers beneath it, one of the primary benefits of advanced regulatory control is that it enables the higher levels, such as optimization and enterprise management and control.

❖ SYMBOLS

Chapter 2 discusses the graphical symbols used in control system documentation. Listed below are the mathematical symbols that are used generally throughout the book. Some symbols used in this book are used only for the discussion of a particular topic; these symbols are therefore defined in that discussion and are not listed here. Chapter 15 uses a unique set of symbols that are defined at the beginning of that chapter. The following are the symbols found throughout this book:

b	bias value (manual reset) on proportional-only controller output
e	error (deviation between set point and process variable)
E	when capitalized, refers to (Laplace) transform of error
K	steady-state gain of first-order lag
K_C	controller gain (noninteractive and interactive control algorithms)
K_D	derivative gain (independent gains control algorithm)
K_I	integral gain (independent gains control algorithm)
K_P	proportional gain (independent gains control algorithm)
K_p	process gain (change in process variable / change in controller output)
m	manipulated variable, controller output

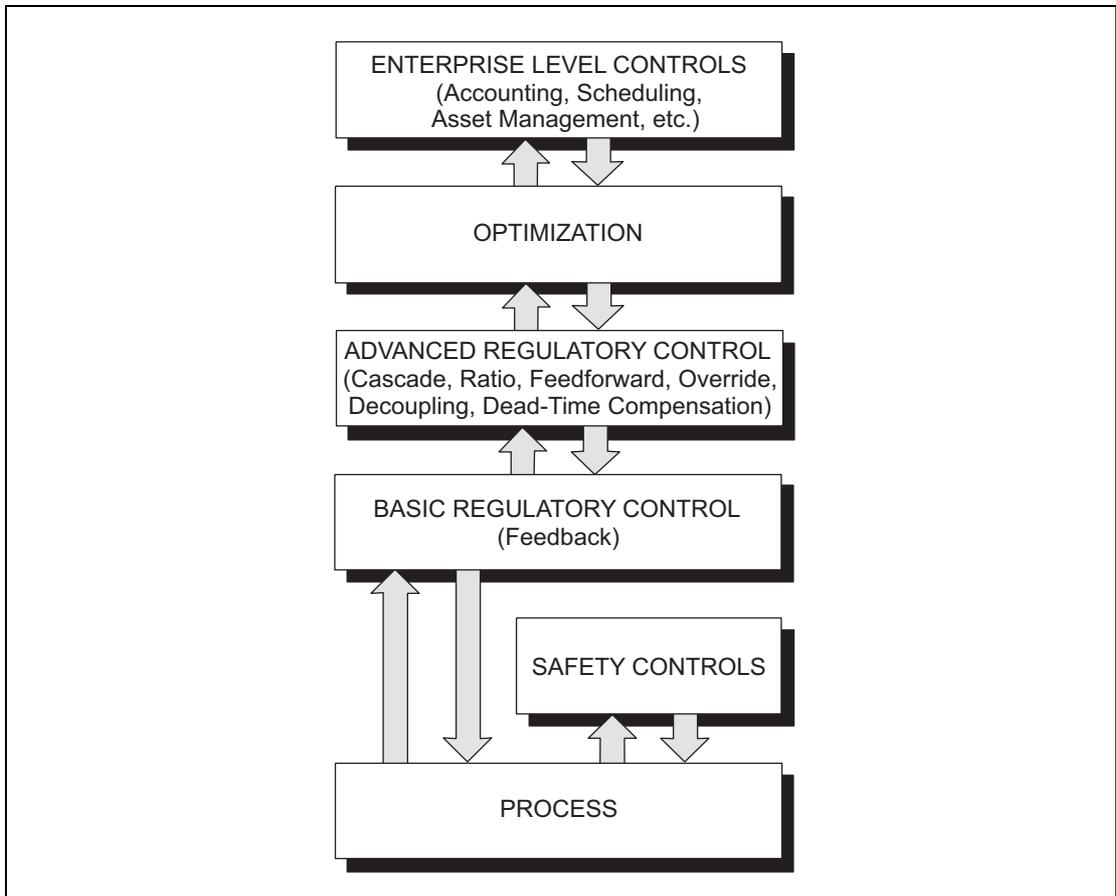


Figure 1-1. Overall Process Control and Information System Hierarchy

- M when capitalized, refers to (Laplace) transform of manipulated variable
- PB proportional band
- PI control algorithm with proportional and integral modes
- PID control algorithm with proportional, integral, and derivative modes
- PV process variable (see also symbol x)
- SP set point (see also symbol x_{SP})
- T_D derivative time (noninteractive and interactive control algorithms)
- T_I integral time (minutes/repeat) (noninteractive and interactive control algorithms)
- x process variable (see also symbol PV)
- x_{SP} set point (see also symbol SP)
- u disturbance variable
- α derivative gain when a derivative filter is used with noninteractive or interactive control algorithm)
- θ dead time
- τ first-order lag-time constant