Chapter 3
Control Architecture and Controllability

CONTROL SYSTEM STRUCTURE DESIGN

Structure Design Problem

Control systems make the plant function in the specified ways, and are the critical components of many products. Controls systems vary in scale and complexity. With increasing functionalities and complexities in modern control systems, the control system structure design is an important step and often does not receive enough consideration from the engineers, in contrast to control algorithm design which is often focused in controls textbooks. Control system structure is the overall structural decisions made on the whole control system: these structural decisions include the selection of manipulated variables, controlled variables, measured variables as well as decomposition of the overall control system into smaller subsystems which are easier to deal with in design. The term control configuration is distinguished from the term control structure in this book. Control configuration is the structure of an individual controller and a control system may include many controllers like autopilot. We will discuss control system structure in this chapter; various control configurations used by individual controllers are introduced in Chapter Four on the controller design.

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Control system structure design has been actively looked at in the process industry because of the needs to design a complex chemical plant which may have thousands of measurements and controls loops. Chapter 10 of Skogestad (1997) discusses the control structure design. Larsson and Skogestad (2000) published a paper on the plantwide control, where a review (references to other earlier works on this topic can be found there) and a new design procedure were given. Skogestad (2004) presented an expanded version of the plantwide control design procedure of Larsson and Skogestad (2000).

In practice, such as in a chemical plant, the control system is usually divided into several layers, (see Figure 1). For the chemical plant example, typically layers include scheduling (timescale of weeks), optimization layer (which is further divided into site-wide optimization (day) and local optimization (hour)), supervisory (advanced) control (minutes) and regulatory (base) control (seconds). These faster and slower layers are separated by different time scales and their relative positons in the hierarchy. The top layer is the planning and scheduling layer, where the overall operational decisions are made. For airplane avionics systems, a flight management system (FMS) is the top planning and scheduling layer. Given the flight plan and the aircraft's position, the FMS calculates the course to follow. The required course can be followed manually by the pilot or automatically by the autopilot (flight control system). The supervisory control layer and the regulatory control layer comprise the control layer, where the feedback control (and other control configurations such as feedforward) is implemented. In the supervisory control layer, the primary controlled variables are controlled to meet the overall system objectives and safety constraints and other constrains are handled. The regulatory control layer does not directly control the system level controlled variables; it regulates the secondary controlled variables. The objective of the regulatory control is to make it easier to achieve the primary control objectives in the supervisory layer. The regulatory control system stabilizes unstable modes, controls variables which otherwise drifts away due to large sensitivity to disturbances using local measurements and loops. The optimization layer determines the optimal operating point considering operational objectives and constraints. The optimization layer re-computes new set points at a longer time interval (i.e. an hour), while the control layer operates at a much short time interval (i.e. a minute and a second). These layers are linked by the controlled variables/measurements, whereby the set points are computed by the upper layer and implemented by the lower layer.

Why do we create layers in the control structure? One might image using a single optimizing controller which stabilizes the process, and at the same

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