

## Chapter 4

# Control System Development

### INTRODUCTION

The control system development process includes the selection of a control configuration and control algorithm development. Besides analytical analysis and numerical simulation, aspects relating to implementation of the control algorithms are important practical issues. This chapter discusses various types of control loops commonly used for industrial control systems. It provides guidelines for controller design, analysis and implementation. Practical examples are used to demonstrate the applications in real control systems.

The intended readers of this chapter include controls engineers, software engineers, hardware engineers, and system engineers with some control engineering background. It is assumed that the reader has taken at least one undergraduate level controls course offered through an engineering program and understands frequency domain control analysis and design techniques such as Bode plot, Nyquist stability criterion, gain margin, and phase margin. The users should also be familiar with linear algebra and matrix calculations.

Controls systems could have multiple actuators (control/manipulated variables) and multiple properties to be regulated and controlled (controlled variables). In other words, they are multi-input, multi-output (MIMO) systems. However, we can apply either single-input-single-output (SISO) design approaches or MIMO design approaches for a MIMO control system.

- SISO control design techniques are used most commonly in industry. SISO tools and methods consider the effect of one control variable (e.g. a DC motor terminal voltage) on a controlled variable (e.g. rotational speed of a DC motor) as if other control variables have little effect on that controlled variable (in controls terminology they are considered as decoupled). Proper decoupling techniques could be used to enable a SISO control design.
- MIMO control system design is less commonly used in industry and usually introduced when there are strong interactions among control variables and controlled variables and independently designing a SISO control loop for each controlled variable becomes insufficient. Also, MIMO techniques are used when control requirements for several controlled variables have to be met simultaneously, where a centralized controller is preferred to multiple independent SISO control loops. MIMO techniques are more difficult to use as they involve advanced system concepts, such as the controllability and observability structural properties, and system/signal norms. The design of MIMO control systems will be briefly discussed in this chapter at a high level.

As discussed above, when the control requirements for a control system are less stringent (which occurs in majority cases in industry), a decentralized controller may be used, that is a single controller is designed for each individual control/controlled variable pair ignoring the interactions with other variables in the plant. This approach results in designing a number of SISO controllers. This chapter focuses on the control design based on decoupling techniques and SISO control methodologies.

When a specific design method is adopted, the reader should reference controls textbooks or literature for details of the method. This chapter only presents what steps should be taken to design an industrial control system and discusses a number of techniques, but does not substitute for formal training in control system design.

Control design in the scope of this chapter includes two steps:

1. Control configuration selection, and
2. Control algorithm development.

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