Chapter 1

Introduction

1.1 Preliminary Remarks

The ability of proportional integral (PI) and proportional integral derivative (PID) controllers to compensate most practical industrial processes has led to their wide acceptance in industrial applications. Koivo and Tanttu (1991), for example, suggest that there are perhaps 5-10% of control loops that cannot be controlled by single input, single output (SISO) PI or PID controllers; in particular, these controllers perform well for processes with benign dynamics and modest performance requirements (Hwang, 1993; Åström and Hägglund, 1995). It has been stated that 98% of control loops in the pulp and paper industries are controlled by SISO PI controllers (Bialkowski, 1996) and that, in process control applications, more than 95% of the controllers are of PID type (Åström and Hägglund, 1995). The PI or PID controller implementation has been recommended for the control of processes of low to medium order, with small time delays, when parameter setting must be done using tuning rules and when controller synthesis is performed either once or more often (Isermann, 1989).

However, despite decades of development work, surveys indicating the state of the art of control industrial practice report sobering results. For example, Ender (1993) states that, in his testing of thousands of control loops in hundreds of plants, it has been found that more than 30% of installed controllers are operating in manual mode and 65% of loops operating in automatic mode produce less variance in manual than in automatic (i.e. the automatic controllers are poorly tuned). The situation does not appear to have improved in recent years as Van Overschee and De Moor (2000) report that 80% of PID controllers are badly tuned; 30% of PID controllers operate in manual with another 30% of the controlled loops increasing the short term variability of the process to be controlled (typically due to too strong integral action). The authors state that 25% of all PID controller loops use default factory settings, implying that they have not been tuned at all.

These and other surveys (well summarised by Yu, 1999, pages 1-2) show that the determination of PI and PID controller tuning parameters is a vexing problem in many applications. The most direct way to set up controller parameters is the use of tuning rules; obviously, the wealth of information on this topic available in the literature has been poorly communicated to the industrial community. One reason is that this information is scattered in a variety of media, including journal papers, conference papers, websites and books over a period of seventy years. The author has recorded 408 separate sources of tuning rules since the first such rule was published by Callender *et al.* (1935/6). In a striking statistic, 293 sources of tuning rules have been recorded since 1992, reflecting the upsurge of interest in the use of the PID controller recently.

The purpose of this book is to bring together, in summary form, the tuning rules for PI and PID controllers that have been developed to compensate SISO processes with time delay. Tuning rules for the variations that have been proposed in the 'ideal' PI and PID controller structure are included. Considerable variations in the ideal PID controller structure, in particular, are encountered; these variations are explored in more detail in Chapter 2.

1.2 Structure of the Book

Tuning rules are set out in the book in tabular form. This form allows the rules to be represented compactly. The tables have four or five columns, according to whether the controller considered is of PI or PID form, respectively. The first column in all cases details the author of the rule and other pertinent information. The final column in all cases is labelled "Comment"; this facilitates the inclusion of information about the tuning rule that may be useful in its application. The remaining columns detail the formulae for the controller parameters.

Chapter 2 explores the range of PI and PID controller structures proposed in the literature. It is often forgotton that different manufacturers implement different versions of the PID controller algorithm (in particular); therefore, controller tuning rules that work well in one PID architecture may work poorly on another. This chapter also details the process models used to define the controller tuning rules.

Chapters 3 and 4 of the book detail, in tabular form, tuning rules for setting up, respectively, PI controllers and PID controllers (and their variations), for a wide variety of process models. P controller and I controller tuning rules are also defined (as subsets of PI controller tuning rules), and PD controller tuning rules are defined (as a subset of PID controller tuning rules), for processes whose model includes an integrator. One hundred and eighty-three such tables are provided altogether. To allow the reader to access data readily, the author has arranged that each table start on its own page of the book; each table is preceded by the controller used, together with a block diagram showing the unity feedback closed loop arrangement of the controller and process model.

In Chapter 5 of the book, analytical calculations of the gain and phase margins of a large sample of PI and PID controller tuning rules are determined, when the process is modelled in first order lag plus time delay (FOLPD) form, at a range of ratios of time delay to time constant of the process model. Results are given in graphical form.

An important feature of the book is the unified notation that is used for the tuning rules; a glossary of the symbols used is provided in Appendix 1. Appendix 2 outlines the range of methods that are used to determine process model parameters; this information is presented in summary form, as this topic could provide data for a book in itself. However, sufficient information, together with references, is provided for the interested reader.

Finally, a comprehensive reference list is provided. In particular, the author would like to recommend the contributions by McMillan (1994), Åstrom and Hagglund (1995), Shinskey (1994), (1996), Tan *et al.* (1999a), Yu (1999), Lelic and Gajic (2000) and Ang *et al*. (2005) to the interested reader, which treat comprehensively the wider perspective of PID controller design and application.