Process Control
A Practical Approach

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Preface

So why write yet another book on process control? There are already many published, but they are largely written by academics and intended mainly to support courses taught at universities. Excellent as some of these books are in meeting that aim, the content of many academic courses has only limited relevance to control design in the process industry. There are a few books that take a more practical approach but these usually provide only an introduction to the technologies. They contain enough detail if used as part of a wider engineering course but not enough for the practitioner. This book aims more to meet the needs of industry.

Most engineers responsible for the design and maintenance of control applications find daunting much of the theoretical mathematics that is common in the academic world. In this book we have aimed to keep the mathematics to a minimum. For example, Laplace transforms are only included so that the reader may relate what is in this book to what will be found in most theoretical texts and in the documentation provided by many DCS (distributed control system) vendors. They are not used in any of the control design techniques. And while we present the mathematical derivation of these techniques, to show that they have a sound engineering basis, the reader can skip these if too daunting and simply apply the end result.

The book aims to present techniques that have an immediate practical application. In addition to the design methods it describes any shortcuts that can be taken and how to avoid common pitfalls. The methods have been applied on many processes on a wide range of controllers. They should work!

In addition to providing effective design methods, this book should improve the working practices of many control engineers. For example, the majority still prefer to tune PID (proportional, integral, derivative) controllers by trial and error. This is time-consuming and rarely leads to controllers performing as well as they should. This might be because of a justified mistrust of published tuning methods. Most do have serious limitations. This book addresses this and offers a method proven to be effective in terms of both controller performance and engineering effort.

DCS include a wide array of control algorithms with many additional engineer-definable parameters. The DCS vendors are poor at explaining the purpose of these algorithms with the result that the industry is rife with misinterpretation of their advantages and disadvantages. These algorithms were included in the original system specification by engineers who knew their value, but this knowledge has not passed to the industry. The result is that there are substantial improvements that can be made on almost every process unit, surpassing what the control engineer is even aware of – let alone knows how to implement. This book addresses all the common enhancements.

This book takes a back-to-basics approach. The use of MVC (multivariable controllers) is widespread in industry. Control engineering staff and their contractors have invested
thousands of man-hours in the necessary plant testing and commissioning. Improving the basic controls is not usually an option once the MVC is in place. Improvements are likely to change the process dynamics and would thus involve substantial re-engineering of the MVC. Thus poor basic control remains the status quo and becomes the accepted standard to the point where it is not addressed even when the opportunity presents itself. This book raises the standard of what might be expected from the performance of basic controls.

Before MVC, ARC (advanced regulatory control) was commonplace. MVC has rightly replaced many of the more complex ARC techniques, but it has been used by too many as the panacea to any control problem. There remain many applications where ARC outperforms MVC; but appreciation of its advantages is now hard to find in industry. The expertise to apply it is even rarer. This book aims to get the engineer to reconsider where ARC should be applied and to help develop the necessary implementation skills.

However due credit must be given to MVC as a major step forward in the development of APC (advanced process control) techniques. This book focuses on how to get the best out of its application, rather than replicate the technical details that appear in many text books, papers and product documentation.

The layout of the book has been designed so that the reader can progress from relatively straightforward concepts through to more complex techniques applied to more complex processes. It is assumed that the new reader is comfortable with mathematics up to a little beyond high school level. As the techniques become more specific some basic knowledge of the process is assumed, but introductory information is included – particularly where it is important to control design. Heavily mathematical material, daunting to novices and not essential to successful implementation, has been relegated to the end of each chapter.

SI units have been mainly used throughout but, where important and practical, conversion to imperial units is given in the text. Methods published in non-SI units have been included without change if doing so would make them too complex.

The book is targeted primarily for use in the continuous process industry, but even predominantly batch plants have continuous controllers and often have sections of the process which are continuous. My experience is mainly in the oil and petrochemicals industries and, despite every effort being taken to make the process examples as generic as possible, it is inevitable that this will show through. However this should not be seen as a reason for not applying the techniques in other industries. Many started there and have been applied by others to a wide range of processes.

It is hoped that the academic world will take note of the content. While some institutions have tried to make their courses more relevant to the process industry, practitioners still perceive a huge gulf between theory and practice. Of course there is a place for the theory. Many of the modern control technologies now applied in the process industry are developed from it. And there are other industries, such as aerospace, where it is essential.

The debate is what should be taught as part of chemical engineering. Very few chemical engineers benefit from the theory currently included. Indeed the risk is that many potentially excellent control engineers do not enter the profession because of the poor image that theoretical courses create. Further, those that do follow a career in process control, can find themselves working in an organisation managed by a chemical engineering graduate who has no appreciation of what process control technology can do and its importance to the business.
It is the nature of almost any engineering subject that the real gems of useful information get buried in amongst the background detail. Listed here are the main items worthy of special attention by the engineer because of the impact they can have on the effectiveness of control design.

- Understanding the process dynamics is essential to the success of almost every process control technique. These days there is very little excuse for not obtaining these by plant testing or from historically collected data. There are a wide range of model identification products available plus enough information is given in Chapter 2 for a competent engineer to develop a simple spreadsheet-based application.

- Often overlooked is the impact that apparently unrelated controllers can have on process dynamics. Their tuning and whether they are in service or not, will affect the result of step tests and hence the design of the controller. Any changes made later can then severely disrupt controller performance. How to identify such controllers, and how to handle their effect, is described in Chapters 2 and 8.

- Modern DCS include a number of versions of the PID controller. Of particular importance in the proportional-on-PV algorithm. It is probably the most misunderstood option and is frequently dismissed as too slow compared to the more conventional proportional-on-error version. In fact, if properly tuned, it can make a substantial improvement to the way that process disturbances are dealt with – often shortening threefold the time it takes the process to recover. This is fully explained in Chapter 3.

- Controller tuning by trial and error should be seen as an admission of failure to follow proper design procedures, rather than the first choice of technique. To be fair to the engineer, every published tuning technique and most proprietary packages have serious limitations. Chapter 3 presents a new technique that is well proven in industry and gives sufficient information for the engineer to extend it as required to accommodate special circumstances.

- Derivative action is too often excluded from controllers. Understandably introducing a third parameter to tune by trial and error might seem an unnecessary addition to workload. It also has a poor reputation in the way that it amplifies measurement noise, but, engineered using the methods in Chapter 3, it has the potential to substantially lessen the impact of process disturbances.

- Tuning level controllers to exploit surge capacity in the process can dramatically improve the stability of the process. However the ability to achieve this is often restricted by poor instrument design, and, often it is not implemented because of difficulty in convincing the plant operator that the level should be allowed to deviate from SP (set-point) for long periods. Chapter 4 describes the important aspects in sizing and locating the level transmitter and how the conventional linear PID algorithm can be tuned – without the need even to perform any plant testing. It also shows how nonlinear algorithms, particularly gap control, can be set up to handle the situation where the size of the flow disturbances can vary greatly.
While many will appreciate how signal conditioning can be applied to measurements and controller outputs to help linearise the behaviour, not so commonly understood is how it can be applied to constraint controllers. Doing so can enable constraints to be approached more closely and any violation dealt with more quickly. Full details are given in Chapter 5.

Many engineers are guilty of installing excessive filtering to deal with noisy measurements. Often implemented only to make trends look better they introduce additional lag and can have a detrimental impact on controller performance. Chapter 5 gives guidance on when to install a filter and offers a new type that actually reduces the overall process lag.

Split-ranging is commonly used to allow two or more valves to be moved sequentially by the same controller. While successful in some cases the technique is prone to problems with linearity and discontinuity. A more reliable alternative is offered in Chapter 5.

Feedforward control is often undervalued or left to the MVC. Chapter 6 shows how simple techniques, applied to few key variables, can improve process stability far more effectively than MVC.

A commonly accepted problem with MVC is that, if not properly monitored, they become over-constrained. In fact, if completely neglected, they are effectively fully disabled – even though they may show 100% up-time. Chapter 8 offers a range of monitoring tools, supplementary to those provide by the MVC vendor, which can be readily configured by the engineer.

There are many examples of MVC better achieving the wrong operating objective; unbeknown to the implementer they are reducing process profitability. Rather than attempt to base the cost coefficients on real economics they are often adjusted to force the MVC to follow the historically accepted operating strategy. Some MVC are extremely complex and it is unlikely that even the most competent plant manager will have considered every opportunity for adopting a different strategy. Chapter 12 shows how properly setting up the MVC can reveal such opportunities.

There are literally thousands of inferential properties, so called ‘soft sensors’, in use today that are ineffective. Indeed many of them are so inaccurate that process profitability would be improved by decommissioning them. Chapter 9 shows how many of the statistical techniques that are used to assess their accuracy are flawed and can lead the engineer into believing that their performance is adequate. It also demonstrates that automatically updating the inferential bias with laboratory results will generally aggravate the problem.

Simple monitoring of on-stream analysers, described in Chapter 9, ensures that measurement failure does not disrupt the process and that the associated reporting tools can do much to improve their reliability and use.
Compensating fuel gas flow measurement for variations in pressure, temperature and molecular weight requires careful attention. Done for accounting purposes, it can seriously degrade the performance of fired heater and boiler control schemes. Chapter 10 presents full details on how it should be done.

Manipulating fired heater and boiler duty by control of fuel pressure, rather than fuel flow, is common practice. However it restricts what improvements can be made to the controller to better handle process disturbances. Chapter 10 shows how the benefits of both approaches can be captured.

Fired heater pass balancing is often installed to equalise pass temperatures in order to improve efficiency. Chapter 10 shows that the fuel saving is negligible and that, in some cases, the balancing may accelerate coking. However there may be much larger benefits available from the potential to debottleneck the heater.

Compressor control packages are often supplied as ‘black boxes’ and many compressor manufacturers insist on them being installed in special control systems on the basis that DCS-based schemes would be too slow. Chapter 11 describes how these schemes work and, using the tuning method in Chapter 3, how they might be implemented in the DCS.

A common failing in many distillation column control strategies is the way in which they cope with changes in feed rate and composition. Often only either the reboiler duty or the reflux flow is adjusted to compensate – usually under tray temperature control. Chapter 12 shows that failing to adjust both is worse than making no compensation. Other common misconceptions include the belief that column pressure should always be minimised and that the most economic strategy is to always exactly meet all product specifications.

There are many pitfalls in executing an advanced control project. Significant profit improvement opportunities are often overlooked because of the decision to go with a single supplier for the benefits study, MVC, inferentials and implementation. Basic controls, inferentials and advanced regulatory controls are not given sufficient attention before awarding the implementation contract. The need for long-term application support is often underestimated and poor management commitment will jeopardise the capture of benefits. Chapter 13 describes how these and many other issues can be addressed.

Gaining the knowledge and experience now contained in this book would have been impossible if it were not for the enthusiasm and cooperation of my clients. I am exceedingly grateful to them and indeed would welcome any further suggestions on how to improve or add to the content.

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