PROCESS CONTROL SYSTEMS

Principles of design and operation

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To my sons
Dražen, Dinko, Alan and Ozren

To the memory of the distinguished men and teachers
Emerik Jović and Zlatko Singer

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Contents

Preface

This book reflects the considerable current industrial interest and investment in process control systems. The use of computer systems in process control can provide great benefits, and it is estimated that efficiency can be increased by up to 30 per cent. It is not surprising, therefore, that there have been considerable efforts by system designers and users to introduce and use such systems.

Process hardware is integrated into a complete production system through data processing. It is for this purpose that technical specialists (eg electrical, mechanical, electronics, communication and process engineers and programmers) are involved in data processing.

The scope of this book is therefore to assist in the selection of computer hardware and software that match the functional specification of the data processing component of a particular system. The principal points covered in this book are set out below:

Part I: Production process hardware for a standard process is outlined and the output process hardware is described. Large mechanical process hardware and process information devices (eg sensors and control elements involved in the process) create a coherent production unit, or system, which can be the control unit (ie the basic process unit). The hardware processes are described and the mathematics explained. This enables the application of control laws in order to linearize the process about its working point, as well as a stratification of process control tasks. Linearization allows process control constants to be reduced and therefore the information capabilities of the computer and communication hardware are also presented and analysed.

Part II: Although the majority of process control tasks can be run using hardware functions, the natural trend towards software process control as more cost-effective is presented. The software tasks in a process control system are dealt with in this part and, in particular, the specific role of software in data processing. The design of the information system based on the software installed in the computer is discussed. These systems may be small, large, free-standing or networked throughout the plant. Additionally, data and functions of system software are presented and are based on an operating system structure. Application programs, their tasks, structure, formation of databases, as well as extended real-time programs, are also described.

Part III: Willingly or unwillingly, operators must interact with the process that is running. True process states are seldom apparent to the operator. By using the approach of complete state description and a reduced presentation to the operator, the only meaningful approach to operator-system-process communication is achieved. Some aspects of human behaviour and work practice are taken into account because they can influence how the system is used.

Part IV: By using methods described in previous parts, a sound practice and a good approach to process control systems can be obtained. However, without a systematic approach to control system design there is only a vague guarantee of successful system application. Specific features (eg software and hardware design, team organization and maintenance procedures) have to be incorporated into a process control system and special attention must be given to control hierarchy and open-endedness of the system. The development and assembly of computer-aided process control presented in this part is based on a feasibility study that concentrates on data volumes, basic system design and cost/benefit analysis.

The numerous standards, recommendations and suggestions cited in this book are based on the work of national and international committees that have been set up to create and codify standards in the field of industrial research and practice. Introduction and utilization of process control systems involve many types of engineer, as well as programmers, and it is essential that they have a good understanding of computer control systems; it is for this audience that this book has been written. However, above all, this book should, by the use of good design practice, provide clear guidelines in determining the most suitable process control systems for specific processes. Therefore, important practices and procedures are reviewed.

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Fran Jović
Zagreb, October 1985

Part I
Systems, Processes and the Role of Process Control Hardware

Chapter 1

Signals, systems and process control

Introduction

A process control system is made up of a process involved in a controlled system and its control equipment or hardware and operators. A typical controlled system is a chemical reactor or a machine tool head, and its respective control equipment is the process controller in the chemical reactor or the positioning system of the machine tool head. Processes are usually analysed on the basis of utilization, since this reflects their proper cost-effectiveness.

Process control hardware encompasses process instrumentation devices, final control devices, process controllers (based on computer units) and communication devices for system interconnection and integration. The role of process control hardware is to support and implement the different process control functions such as regulation, on/off control, process protection and process supervision. The design of this hardware is based on a functional analysis of the entire process. The entire process can be broken down into *basic process units* and controllers which are designed to implement the functions of each basic process unit. Controllers are implemented for each different functional system for specific process control functions and communication hardware is installed to carry process and regulatory data between controllers.

The general rules of signal generation, data acquisition, data processing, data communication, command execution and process actions are governed by information processing. The performance of the process control system therefore is dependent on the effectiveness of the information processing in the process devices and controllers and on their interconnections, input/output devices and coordination.

Part 1 of this book gives analytical and practical tools for the design of process control hardware from a functional and informational standpoint. Thus a simple analysis of process control hardware can be achieved by studying process control devices and controller design.

Chapter 1 describes the functions of process control systems and develops some analytical tools for the design of process control systems. A typical process control system includes a process, a process controller and a process operator. Since signals carry useful information between these parts, a description of signals and their information content is also presented in this chapter. The hardware systems are also described based on the response function concept and each system part is considered as a system in itself and then the parts are integrated into the complete system.

Since the basic functions of such a system can be modelled, implemented or optimized using computers, a brief description of automata is also given.

Processes are classified according to their utilization criteria. Analytical relations are given for some linear and nonlinear processes in order to support their design into bigger system parts. The rules for connecting process and process controllers are presented and analysed according to the change of the response function and their static and dynamic behaviour.

A system approach to process control systems

INTRODUCTION

This part describes a computer system designed for production control and the analysis and design of such a system. It also explains what is meant by a production process and a production plant. A production control system is developed, installed, used and dismantled by man, therefore the roles of the designer, engineer, operator, etc are also considered.

Before a production system can be developed and implemented, it must be decided whether such a system is really necessary. Therefore, a preliminary (or feasibility) study should be carried out. Production plants consist of large mechanical hardware units and their interconnections. These ensure materials and energy storage, processing, exchange and recycling. Examples include reservoirs, condensers, heat exchangers, heaters, pumps, motors, transformers, generators, vessels, reactors, etc. Integrated into large units, or plants, it is these units that enable production – with associated energy and materials transfer – to be carried out. Such units include power plants, liquefied gas storage, machine tools, rolling mills and pipeline systems. The integration of units in a production plant is complemented principally by hardware elements such as pipes, valves, power cables, pulleys, conveyors, gears and clutches.

Individual units in a plant are often fitted with sensing and control elements – typically, temperature indicators, level indicators, pressure indicators, valve motor controllers, electrohydraulic flow controllers, pump motor controllers, etc. Measuring, sensing and controlling the *process variables* (eg temperature, voltage and flow and control of interconnections and control elements) can be used to control each particular production unit. An integrated group of production units controlled in an appropriate way constitutes a production plant.

Several production processes or plants may be integrated into a larger system known as a production system, electrical or natural gas network, which is monitored and controlled via communication and computer networks.

Control system development starts with a feasibility study, followed by a design study which includes the design and realization of computer hardware and software. Finally, to complete the control system development cycle, the system is put into operation. Two modes of work on control system development may be distinguished as:

1 *Problem-oriented work:* this includes the functional specification, specification of data and information flow analysis. It requires a a multidisciplinary approach. (It is important that the customer is consulted at this stage of the development cycle.)
2 *Data-oriented work:* this includes the design study, design of computer hardware and software, implementation and operation changes. It also involves matching the external functions of the control system with the chosen hardware and software. Basically, this work is the responsibility of hardware and software designers. The development cycle of a control system is presented in Figure 1.1.

THE COMPUTER CONTROL SYSTEM

A typical computer control system of a power plant is illustrated in Figure 1.2. The power plant is divided into power-generating blocks that are monitored from the operator's console. Here all necessary measurements and recordings are made, and all report and alarm warnings are issued. Process control is performed using an algorithm based on 'block model' software that controls both set-points and functional groups. A separate protection system operates issuing shutdown commands to the block as required; signal conditioning, drive controls, interconnections, signal transducers and drives are called process hardware components. The functions of data processing for supervision, measurement, recording, issuing a protocol, protection, block and group control are all performed by a few *functional systems.* Nevertheless, all these systems use data from the same set of plant data and therefore the basic functions of a process control system are formed by functional systems that are subsystems of the control system itself. In simple process control applications, the functional system is used as a single process control device (eg an alarm unit of a distillation column, or the current controller of the power supply in rural areas).

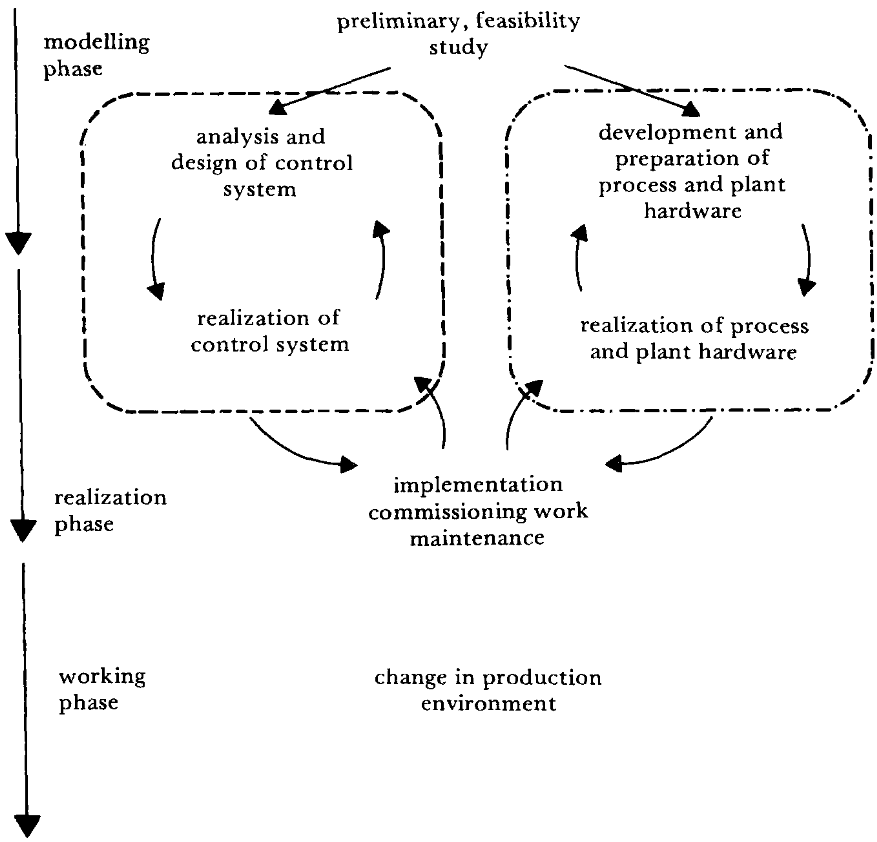

Figure 1.1 *Development cycle of a control system:*

— — —, control system development;
—·—, process hardware development