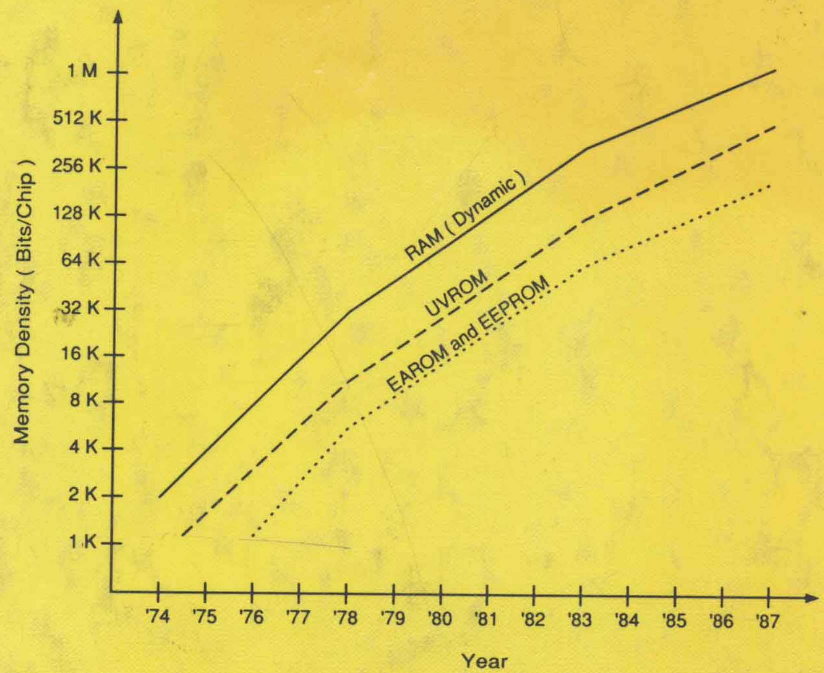
Distributed Computer Control for Industrial Automation



Dobrivoje Popovic
Vijay P. Bhatkar

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Dobrivoje Popovic

Institute of Automation Technology
University of Bremen
Bremen, Federal Republic of Germany

Vijay P. Bhatkar

Centre for Development of Advanced Computing
Pune, India

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PREFACE

The field of distributed computer control is now a decade and a half old. Its birth more or less corresponds to the emergence of low-cost microcomputers in the early 1970s. Since then, distributed computer control systems have evolved continuously and their applications have become widespread throughout the process industry. Application areas of the DCCS include chemical and petrochemical plants, oil refineries, utilities, iron and steel industries, cement mills, pulp and paper mills, food industries, water and wastewater treatment works, oil and gas fields, and the like. The DCCS applications are also steadily reaching laboratory automation and large research experiments, as well as discrete and manufacturing industries. In all newly constructed process plants, DCCS are now being used as a universal automation tool. Their use in existing plants to replace the conventional analog instrumentation is also becoming widespread.

From the point of view of process engineers, this field has contributed to improved plant productivity, enhanced quality of products, better safety and reliability, greater flexibility of operations, and increased visibility into the process itself. From the computer and control engineers' viewpoint, the field has proven to be a springboard for the application of fast growing computer and communications technology and rich control theory, leading to increasingly advanced industrial automation systems. We are now witnessing the arrival of the second generation of distributed computer control systems providing plant-wide integrated information and control systems. The steady convergence of computer, communications, and control technologies is bringing together diverse disciplines giving birth to new technologies and benefiting the industrial development in an unprecedented manner.

The aim of this book is to provide university students and professionals in the industry who already have a basic knowledge in control and computer engineering with a systematic and comprehensive exposition of present technology and applications of modern distributed computer control systems. Our objective is to capture the essence of DCCS in terms of their general structure, functional elements, data links, software, and algorithms, and relate each aspect to the practical systems, in addition to providing application examples of DCCS in the industry. Not only are most recent developments in the field covered, but future technology trends are also projected.

In spite of the great impact of DCCS on industrial automation, there are at present only a few books available on the subject. And, to our knowledge, no text in this area covers the subject of DCCS for the requirements of both students and professionals in the industries. The book is designed to serve as a reference volume for systems and project engineers engaged in the application of DCCS, instrumentation engineers planning to introduce DCCS in new or existing plants, consulting engineers specifying and evaluating available systems, and R&D engineers developing microcomputer-based control equipment. Managers of industrial enterprises will also benefit from the selected application and technology coverage.

The book can also be used either as a text for a course on DCCS or as a self-study guide for instrumentation and computer professionals who wish to have a deeper knowledge of DCCS. It should be possible to cover the essential contents of the book if it is used as a text for a two-semester comprehensive graduate course in DCCS. Selected chapters can also serve as a text for one-semester courses in various topics. For instance, Chapters 2, 4, and 7 can be used for a course in data communication systems, while Chapters 3, 5, and 6 can be used for a course in programmable multiloop controllers. Both courses can be complemented by the relevant parts of Chapters 8 and 9.

We expect readers to have a requisite background in instrumentation and control systems, as well as in microcomputer hardware and software. Practicing engineers should have experience with instrumentation and computer applications. For readers who would like to refresh their knowledge in prerequisite areas, we have recommended some background reading in the references.

In order to bring the reader close to the subject matter, Chapter 1 begins with an introduction to the problems to be solved by plant automation. A short review of the evolution of automation approaches follows, starting from the conventional instrumentation and leading to the computer-based systems, prior to the introduction of DCCS. This review provides an insight into the individual techniques and methods that have already been available for solving plant automation problems, and whose appropriate integration leads naturally to the concept of modern distributed computer control systems.

In Chapter 2, a conceptual description of a typical DCCS is presented, based on the distributed and hierarchical nature of the functions to be implemented for automation of a complex industrial plant. A step-by-step evolution of the computer control system architecture, culminating in the present hierarchical system structure, is first given. The functional levels of a modern integrated control system are identified as process control, plant supervisory control, production scheduling and production management. The database organization within a hierarchically structured system is then presented. There are various possible approaches for implementing the decentralized hierarchical system structure of a DCCS. The most representative of them are delineated by exemplifying the structures of the relevant, well-known available systems.

The understanding of functional layering is important for the classification of system elements, including their linkages and interfaces to the plant operator. This is the main concern of Chapter 3, which focuses on individual system elements within the DCCS. Here, system elements at different hierarchical levels are described in terms of their hardware configuration, functionality, and programming, as well as their respective roles within the overall system. The explanation of system elements is done on a balanced choice of examples of DCCS available in the United States, Europe, and Japan.

Chapter 4 describes data communication links that connect the individual functional elements to form a DCCS. An in-depth knowledge of data communication is essential for understanding the data flow between the functional layers and for grappling with compatibility problems when integrating the system for a given application. This chapter also presents the state-of-the-art of standardisation of bus systems and local area networks (LAN) with specific reference to the activities of IEEE, ISA, ISO, and IEC in this area, including the MAP concept described for future computer integrated manufacturing. The chapter concludes with examples of data communication links that are available in the commercial DCCS.

Chapter 5 covers the software concepts and program development tools within the DCCS. Here, the system software necessary to run the application programs, perform real-time background calculations, and implement new programs is described. However, the main concern of this chapter is application software, particularly its modularity concept, system generation technique, and system configuration and parametrisation approach for real-time applications. At the end of this chapter, a preview of the knowledge-based software expected to be the future application software for complex automation problems is given. This chapter is essential for understanding the implementation of application algorithms, described in the next chapter.

The algorithms delineated in Chapter 6 are classified according to their tasks and usually organised within a library of functions of an implemented DCCS. Their selection is based on process control and plant monitoring problems to be solved by the application of an automation system. The modularity concept is at the heart of implementation of the algorithms as individual program blocks or program modules. This is illustrated by some examples of program modules, generated and integrated into the library of functions according to standardised rules to be followed. In this way, the user is given an exact knowledge of the meaning of individual block parameters needed for their efficient applications.

Chapter 7 addresses the aspect of reliability of DCCS as the most important application requirement. First, the basic hardware reliability concept of systems is defined, especially of multi-computer systems. These definitions are then extended to the software system, so that both the designer and the user of computer-based industrial automation systems are made aware of the role of such parameters, as system availability, fail-safety, fault-tolerance, etc. in design and use of such systems. Based on this, some guidelines are given for design of reliable DCCS and the most typical reliability concepts of available DCCS presented.

Chapter 8 focuses on the applications of DCCS within process industries. The application sectors chosen are power plants, iron and steel plants, cement plants, chemical plants and other process industries such as pulp and paper, glassmaking, water and waste water treatment, and gas production. The choice of application examples has been guided by the authors' specific practical experience in computer-based industrial automation. In each application, examples of process description, automation trends, DCCS applications, and advanced control implementation are covered. This chapter should provide both students and practising engineers a closer insight into real-life applications of DCCS, as the examples presented are actual industry applications of available DCCS.

Finally, Chapter 9 summarises the state-of-the-art in the field and indicates enduring trends that are fast emerging. The state-of-the-art is presented through a review of important features of well-known DCCS that are now available in the market place worldwide. Also given is a short survey of 22 major systems available in the United States, Europe, and Japan. Following this overview, state-of-the-art programmable controllers are presented, including a comprehensive tabular review of some well-known systems in the market. The state-of-the-art report is followed by an enunciation of factors that are impacting the evolution of DCCS. These include VLSI, sensors, computers, communications, software, and computer-aided control system design. Next generation DCCS are expected to contain a significant component of artificial intelligence in the form of expect systems or knowledge-based systems. With this in view, the likely impact of artificial intelligence on process control is sketched. This chapter provides valuable information regarding technology trends in the field.

The book is drawn from various courses and reference materials prepared by us during the last six years at the Institute of Automation Technology of the University of Bremen, Federal Republic of Germany, the Electronics Research and Development Centre, Trivandrum, India and the Tata Research Development and Design Centre, Pune, India. We have also drawn from our research experience in the design and development of advanced microcomputer-based control systems, and practical experience in specifying, evaluating, and applying available DCCS in power, iron, and steel plants, and some process industries. While preparing the text, we have referenced recent papers on the subject from international conferences and workshops, as well as the available industry literature and application notes on DCCS from major vendors.

The references, which are organised by chapter, will guide the reader into different aspects of the study of DCCS. Included are references on basic books in control and computer engineering, introductory readings on the DCCS, and an extensive selection of technical publications relating to individual subjects.

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Vijay P. Bhatkar

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CONTENTS

1

Introduction and Overview

The term *industrial automation* generally refers to the science and technology of process control and includes the control of chemical and petrochemical plants, oil refineries, iron and steel plants, power plants, cement mills, paper pulp and paper mills, pharmaceuticals, food and beverage industries, water and wastewater treatment plants, oil and gas fields, and the like. The industrial revolution witnessed the development of process industries when machines substituted for human physical power. The early production processes were natural scale-up versions of the traditional manual practices. They were usually designed as batch processes. Later, continuous processes were introduced which brought about some economic and technological benefits. Over the years, there has been an increasing trend towards larger and more complex plants to take advantage of the economies of scale and technological developments.

Contrary to what is generally understood, industrial automation is in no way a discovery of the recent past, but is rather as old as the industry itself. From the very beginning, the designer of an industrial production system has attempted to make it run as autonomous as possible, based on the available instrumental tools. Furthermore, there has been a continual development of industrial processes, which required the development of better instrumentation. Conversely, the advancements in control and instrumentation made possible the development of larger and more complex processes, bringing numerous new technological and economic benefits.

The accelerated development trend in the area of industrial automation over the last two decades is a direct consequence of technological innovations and theoretical advances in the area of systems engineering. Automation is presently viewed as a versatile tool for solving crucial problems of process and production control, plant supervision and management, as well as for solving the accompanying financial and organizational problems. Nowadays, *full scale automation* of typical industrial sectors like electric power generation and distribution, iron and steel, cement, paper, chemical, petrochemical and pharmaceutical plants, oil and gas field exploration, food and beverages processing, water and wastewater treatment, etc. is commonplace.

Likewise, the factory automation in the manufacturing sector has also benefited from automation trends, where high technology equipment and most advanced methods are merged to create what is known as *flexible manufacturing*, an automation level at which manufacturing cells on the factory floor are integrated. This has provided for a smooth adaptation to the changing manufacturing demands and for optimal use of manufacturing and transport facilities, and assured a high and uniform product quality, and optimizing material and energy flows, etc. This has led to the concept of *computer integrated manufacturing* (CIM). The CIM concept is aimed at enhancing monitoring and control of production, facilitating planning and design of products, lowering material and energy costs, just-in-time delivery, etc.

Besides in industrial and manufacturing sectors, the modern automation concepts have also found several applications in surface, air, and water transport, as well as in the space missions.

Several factors have contributed to the development of modern automation technology, particularly the following had a decisive impact :

advances in microprocessor, memory, and related VLSI technology
developments in intelligent semiconductor sensors and fiber-optic sensors

implementations of programmable controllers
standardization of modular hardware and software for process control
advancements in computer technology
emergence of powerful interactive graphics for human interface
standardization of data communication links and networks
adoption of a whole range of methods of modern control and system theory (model building, estimation theory, optimal, adaptive, self-tuning control, etc.) for modeling, simulation, and design of control systems
developments in artificial intelligence and methods of knowledge engineering

In this chapter, we shall first review the general aims of plant automation and the benefits that accrue from it. We shall then see how control and automation evolved from conventional instrumentation to computer-based control, leading to the present day distributed computer control. This will provide an insight into the individual techniques and methods that have already been available for solving plant automation problem, and whose appropriate integration has led, in a natural manner, to the concept of modern distributed computer control systems.

1.1 AIMS OF PLANT AUTOMATION

There are three main flows determining an industrial process: *material, energy*, and *information flow*. The basic objective of plant automation is to identify the information flow, and to manipulate the material and energy flows of a given process in a desired, optimal way. This, as a rule, is a compromise between some economic and some quality factors and should lead to some benefits. The most common benefits of automation are :

production volume enhancement
production cost reduction
productivity increase
product quality improvement
optimal production flexibility
optimal production scheduling