



INDUSTRIAL CONTROL SYSTEMS

Edited By

**Vipin Chandra Pal
Suman Lata Tripathi
and Souvik Ganguli**



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Preface

Human civilization started by controlling natural parameters, like fire for making food, water for irrigation to produce grains, creating housing and other products out of wood, etc. Products have turned into a daily need for the people. Controlling input parameters leads to the advancement of manufacturing and other industries. Therefore, advancement of control theory is always a primary focus of research in the development of industry. In view of modern industries, the journey of industrial control systems may be viewed from the control of steam engine to spacecraft, airplane missile control systems to networked control systems, and cybersecurity controls in the new emerging field of robotics. More specifically, in terms of controllers, the journey of the industrial revolution started from the design of P-I-D controllers, fuzzy controllers, neuro-fuzzy controllers, back stepping controllers, sliding mode controllers, and event-triggered controls for networked control systems. Recently, control theory has spread its golden wings in different fields of engineering by use of splendid tools of the control system. In this era, the boom of Internet of Things is exploding at a maximum pace. Different biomedical applications also come under this umbrella and provide the easiest way for continuous monitoring. Some of the prominent research areas in green energy and sustainable development in which control is playing a vital role is as a load frequency controller to control solar thermo plants, event-driven building energy management systems, speed-sensorless voltage and frequency control in autonomous DFIG-based wind energy, hazardous energy control programs, and many more. This book aims to cover all of these subjects and more, in our push to further the field of industrial control systems. We hope this is useful for engineers, scientists, industry professionals, students, and faculty at all levels.

Organization of Book

This book is composed of two parts which contain 13 chapters. Part 1 begins with an introduction to different control techniques which are

used in the industrial revolution for making modernization in industry. Chapter 1 describes the history of industry and also classifies the different categories of industries. The primary concerns of working in industry are safety and precautions. The safety monitoring and control of an industrial boiler is explained in Chapter 2 for preventing major accidents in the plant. Chapter 3 reviews the existing literature in controller design for robust control of rotary machineries involved in many industrial applications which are often subjected to position dependent disturbances. A modified robust approach of finite dimensional repetitive controller design and its synthesis is proposed here. After safety, security is a major concern of many precious machinery and other equipment which are used in real time application in Chapter 4. Chapter 5 proposes about advanced adaptive control applied to nonlinear plants. In Chapter 6, the discussion of optimization algorithm PSO and SVM is included and it is analyzed that they are responsible for identifying the appropriate controls for various operating conditions. Two popular algorithms, viz. the firefly technique abbreviated as FA and the pattern search (PS) technique, are combined to develop a new topology termed the hybrid firefly algorithm, designated in Chapter 7 as the FAPS method. Motivated to re-design some of the essential subsystems of a DC micro-grid for efficient power management in a more informative and user-friendly manner, Chapter 8 represents a virtual instrumentation metering infrastructure and a modern ICS (Industrial Control System) for the same.

Part 2 starts with the real time implementation of different control strategies to practical systems.

Chapter 9 proposes an Adaptive Fuzzy Optimal Power Controller (AFOPC) for speed regulation of Brushless Direct Current Motors (BLDCM) and by using this technique, it is feasible to achieve the lowest possible losses while maintaining the highest possible motor speed. New industrial development is going into new dimensions by including robots for different manufacturing industries where humans are not able to work. In Chapter 10, a Fuzzy logic based partially-optimized FOPID controller is developed mainly focusing on controlling robot manipulators. Chapter 11 represents a brief study, analysis, validation, and control of an electromagnetic attraction type levitation set-up where a flat plate has been successfully levitated at a desired operating point. The final product of any industry is used by consumers worldwide and petrol/diesel based transport is a common facility for receiving items by customers. To protect the environment from pollution, the automobile industry is shifting towards the electric vehicle. In Chapter 12, two-area MSIPS with nonlinearities is attempted to examine the effectiveness of a proposed SSA tuned CTI-TID

controller on electric vehicles. The modern era is the transfer of information through a single click via different networks. Therefore, security and control are very important and from here the new emerging field of Cyber Security Control Systems is gaining prime importance. In Chapter 13, cyber security control systems for operational technology have been discussed.

Part 1

**ADVANCED CONTROL
TECHNIQUES**

Introduction: Industrial Control System

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Abstract

In this chapter, the meaning of industry and the types have been discussed. The history of industry and their way of working are described to focus on the beginning of industry. Finally, the future of industries has been discussed with consideration to the new recent technology in different fields like communication, networking, etc.

Keywords: Industry, revolution of industry, classification of industries

An industry is a collection of firms that have common basic business operations. In today's economy, there are hundreds of industry categories. Typically, industrial groupings are grouped together into larger groups called sectors.

Individual firms are classified into industries based on their principal sources of revenue. Despite the fact that a vehicle manufacturer's finance sector may account for 10% of total sales, most categorization methodologies identify the firm as part of the automobile industry.

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1.1 Types of Industry

On the basis of raw materials and their processing, industries can be divided as follows.

1.1.1 The Primary Sector

Forestry, agriculture, fishing, quarrying, mining, and mineral exploitation are all part of a country's economy. It can be divided into two categories:

- **Genetic Industry** - This category comprises any raw material manufacturing that can benefit from human involvement in the development process.
- **Extractive Industries** - This category involves the development of finite raw materials that cannot be replenished by cultivation.

The primary industry continues to dominate the economies of underdeveloped and growing countries, but as the secondary and tertiary industries increase, its share of total economic output decreases.

1.1.2 The Secondary Sector

The manufacturing industry (secondary industry) processes the raw materials given by primary industries and converts them into consumer goods. Products that have been included into product lines by specialised secondary industries are subjected to additional procedures. These industries develop capital equipment for the production of both consumer and non-consumer goods. The industry is further subdivided into the following categories:

- **Large Scale Industry** – It necessitates considerable capital investment in plants and equipment, provides a varied variety of industries, such as other industrial sectors, has a complex industrial organisation that typically employs qualified experts, and generates a large volume of output. Examples include steel and iron production, petroleum refining, and other sectors.
- **Small Industry** – It is characterised by the non-durability of industrial goods and cheap cost of capital in plants and machinery, which may include nonstandard things like customised or design work [1]. Manufacturing of plastics, textiles, food processing, and other sectors are examples.

1.1.3 The Tertiary Sector

The tertiary industrial sector, sometimes known as the service industry, combines industries that provide services or generate revenue without producing tangible items. This sector is often a mix of government and private firms in free market and mixed economies.

Real estate services, banking and finance services, communication services, and so on are examples. An old, well-known anecdote on industrial control.

Throughout history, individuals have gathered to discuss and learn about strategies to exercise organisational control to claim moral authority and political power. Norms concerning effective conduct patterns have arisen through such exchanges and some of these norms have been codified in codes, principles, laws, adages, edicts, and maxims, or the discursive artefacts that people employ to exert political power and claim moral authority.

People have created stories tying situational facts to behavioural norms and institutional settings in order to explain how an organisation exercised control at a specific time and location. People's assumptions about organisational control have evolved throughout time and these assumptions have shaped the stories they have told. This examines how organisational control has been viewed throughout history.

We will start with one of the few times that contemporary organisational scholars have directly addressed the content of this vast human legacy. Rindova and Starbuck (1997) go into detail about how the ancient Chinese viewed organisations and how they employed agency relationship conceptualizations to build different strategies to wield organisational control. Then, we will look at how the exercise of organisational control evolved over time in eighteenth-century Europe and then America [2]. Specifically, we show how industrial bureaucracies arose and how people often resisted the organisational limitations that came with them. We look at how this resistance sparked efforts to make organisational governance more democratic and sensitive to human needs.

1.2 Historical Perspective in Terms of Control

The factory was the first expression of the capitalist firm, which was created by capitalism. Historical events have indicated that important alterations in business organisation have coincides with industrial revolutions since their inception. The British Industrial Revolution (BIR) gave birth to the factory and the Second Industrial Revolution (SIR) gave birth to the massive contemporary business firm by the 1920s.

A multidivisional kind of business organisation is the name given to this type of firm structure (M-form). Another key transformation in business organisation is occurring as a result of today's ICT revolution: "huge vertically integrated" firms are becoming flatter, decentralised, and organised in "semi-autonomous project-based teams". This revolutionary business organisation is commonly referred to as a project-based firm revolution in the literature [3–7].

What is driving these huge organisational changes in businesses? Do these changes put the firm's core values in jeopardy? These are clearly questions about the evolution of a firm and they are questions that are not addressed in post-coasean conceptions of the firm (e.g., Williamson, 1985 [13]). Nonetheless, there is little doubt that studying a firm's growth can aid in gaining a deeper knowledge of it.

In the context of the co-evolution of social and physical technologies, a historical study of the firm's evolution will be developed [14, 15].

The argument will be that the history of the company must be regarded as part of this co-evolutionary process, which has been mostly driven by big changes in physical technology, or macro-inventions in Mokyr (1990) [16] terms, as historical events reveal. The above three firm organisations must be regarded as mutants according to the theory of the firm and the fundamental difference between them is connected to the shift in the mix of low and high-powered incentives (Williamson, 1985) applied within a given mutant-firm.

Human creation procedure also converts as an output of scientific enhancement. The industrial insurrection refers to a shift in production technology which is vastly unlike its old cohort. People's works circumstances and lives were dramatically altered by new industrial technologies. What was the industrial insurrection like and where do we stand? "From the First Industrial Revolution to Industry 4.0" is the title of a new book.

1.2.1 First Industrial Revolution

The utilisation in the eighteenth century of mechanisation and steam power in production ushered in the 1st Industrial Revolution [3]. The automated version, which previously employed simple revolving wheels to generate threads, now produces 8 times the total in the same amount of time. Steam's power was also well acknowledged. The harnessing of human output for industrial goals was the most significant step forward in increasing human productivity. The steam engine could be utilised to power weaving looms instead of muscle power. Next, an enormous swap occurred as an output of enhancement such as the steamship and the steam-powered locomotive that allows passengers and things to move a great displacement in minimum time.

1.2.2 Second Industrial Revolution

The search for electricity and congregation line production announced the 2nd Industrial insurrection in the 19th century. Henry Ford took these concepts and applied them to the production of automobiles, remarkably changing the factories. Initially, a complete automobile was developing at only a station, but now automobiles were produced in parts on a conveyor belt, which is rapid and more economic.

The Second Industrial Revolution began in the nineteenth century with the creation of electricity and the introduction of construction lines.

At a butchery in Chicago where pigs were stretched on conveyor belts and every butcher only accomplished half of the task, Henry Ford (1863-1947) developed the concept for mass production. Henry Ford took these ideas and applied them to the automobile industry, drastically altering it in the process. Previously, a whole vehicle was built at a single station, but now, cars are built in stages on a conveyor belt, which is significantly accelerated and less expensive.

1.2.3 Third Industrial Revolution

The foundation of “memory-programmable controllers and computers to partially robotize activity kicked off the Third Industrial Revolution in the 1970s of the twentieth century”. We may now robotize a whole industrial activity without the requirement for personal involvement in regards to the adaptation of these modifications. This is exemplified by robots that follow pre-defined commands without requiring personal intervention. In the 1970s, the use of memory-programmable controllers and computers ushered in the Third Industrial Revolution. In regards to technological advancements, we can now automate an entire production process without the requirement for human participation.

1.2.4 Fourth Industrial Revolution

During the 1st Industrial Revolt, water and steam were used to mechanise industries and thee Secondary used electric power to accomplish mass production. The Third used electronics and computer technology to automate production. A Fourth Industrial Revolution is presently being developed upon the Third Industrial Revolution, the digital revolution. It is explained by a merging of technology that makes the boundaries between the biological, digital, and physical realms.

Currently, the 4th Industrial Revolution is underway. The application of data and communication technologies in the manufacturing business

is referred to as “Business 4.0.” It is built on the accomplishments of the 3rd Industrial Revolt. A network link powered computer-based manufacturing system, which has a digital counterpart on the Internet in certain aspects can communicate with another system and get data about each other as a result of this. This is a step forward in the process of manufacturing robotization.

All systems are linked, resulting in “cyber-physical production systems” and sophisticated businesses including creation systems, goods, and people. All systems are linked and the outcomes in “cyber-physical production systems” and smart industries, in which manufacturing equipment, and people interact in a network and production is almost independent.

When these authorizations are combined, “Industry 4.0” has the ability to significantly enhance manufacturing settings. Self-organizing logistics include machines that can discover issues and inform maintenance operations on their own or self-organizing management that adapts to unplanned moves in production.

It also has the capability to influence people’s work routine. People may be drawn to smarter networks as an outcome of Industry 4.0 that might lead to more efficient work.

The 4th Industrial Revolt, like its predecessors, has the ability to raise world income levels and modify people’s lives all throughout the globe. Consumers who can bear and get permission to the digital world have reaped the biggest benefits thus far, as technology has allowed new items and services that increase the enjoyment and efficiency of our lives. Any of these operations, such as hailing a cab, booking a ticket, buying a product, watching a movie, or playing a game, may now be completed remotely. Technological developments will provide a supply-side miracle in the future, resulting in long-term increases in efficiency and production. Communication and transportation and costs will fall, while arrangement and world supply chains will enhance and trade costs will fall, opening up new markets and propelling economic development.

1.3 Future of Industry

1.3.1 Edge Computing

The usage and collection of data distinguishes the third and fourth industrial revolutions. We need technology that allows us to use production information more quickly at any time, regardless of location, in an increasingly competitive and international environment.