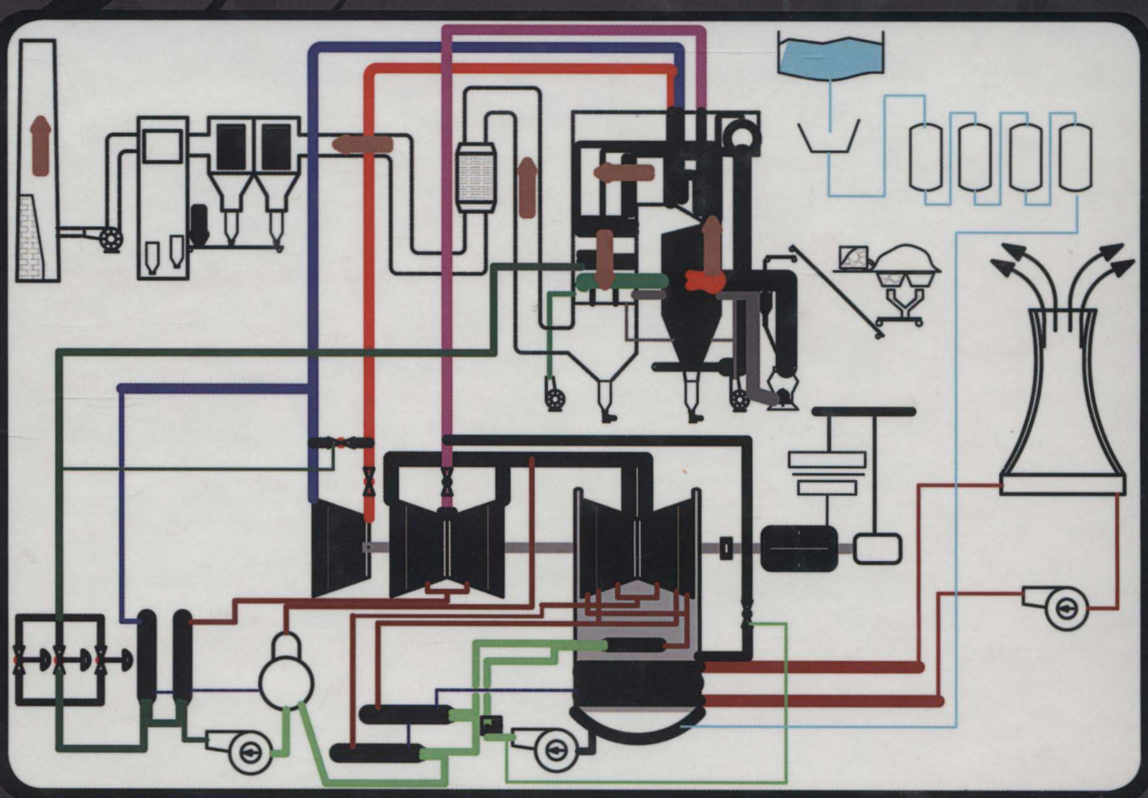
# POWER PLANT INSTRUMENTATION AND CONTROL HANDBOOK

## A Guide to Thermal Power Plants

SWAPAN BASU AND AJAY KUMAR DEBNATH



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SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Academic Press is an Imprint of Elsevier

Academic Press is an imprint of Elsevier
32 Jamestown Road, London NW1 7BY, UK
525 B Street, Suite 1800, San Diego, CA 92101-4495, USA
225 Wyman Street, Waltham, MA 02451, USA
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK



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**British Library Cataloguing-in-Publication Data**
A catalogue record for this book is available from the British Library

**Library of Congress Cataloging-in-Publication Data**
A cataloge record for this book is available from the Library of Congress

ISBN: 978-0-12-800940-6

For information on all Academic Press publications
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Printed in the United States of America

# Power Plant Instrumentation and Control Handbook

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# Dedication

This book is dedicated to the promising and growing engineers working in/around or studying thermal power plant instrumentation and control systems who can render services to mankind by providing sparse, pollution-free energy for human progression.

# Foreword

With the advent of technological advancement in all the fields, knowledge and know-how are now available, in bits and pieces, with just a click of the mouse, on the computer. However, it can be time-consuming to find the desired information in a consolidated manner, or it may be difficult to find the exact subject information required.

Modern power plant engineering is a vast subject with different fields of application for all branches of technology. In this book, the authors have included their experiences from a different angle focusing on instrumentation and control systems.

There are number of valuable books available on power plants covering different subjects, but there is a dearth of a single volumes incorporating the majority of the equipment in relation to the process. The chapters of this book cover various subjects on the process and associated instrumentation with alternative arrangements (if any). The text is well demonstrated with facts and figures that make this book easy to understand.

In general, this book accentuates both subcritical and supercritical plants, and there are separate appendices covering supercritical plants as well the emerging demand for the higher efficiency and lower pollution aspects of subcritical plants.

The authors worked for decades with leading consulting firms in India and abroad and keep in touch with modern technology. I truly feel that their experiences will greatly benefit both practicing engineers and students of power plant engineering.

I wish every success to the authors of this book.

**S. K. Sen**

# Preface

Technical books that have theoretical and practical approaches are available worldwide about several subsystems of thermal power plant instrumentation and controls. This book endeavors to act as a way to balance two extreme lines of thinking, giving a comprehensive approach to plants' measurements and controls.

What is here is primarily meant for professionals working with thermal power plant instrumentation and control systems. Budding (fresh) engineers who start their careers in thermal power plant instrumentation and control engineering, and those practicing professionals of other disciplines, will greatly benefit from the comprehensiveness and practical approaches in this book. It will be a very good reference for engineering students who are pursuing higher-level studies in various branches of engineering.

Highly developed and advanced mathematical deductions are passed up as much as possible; instead physical explanations have been given so that readers get a proper feel of the system so that the book could be kept within a very limited dimension. The text part incorporates an abridged description on the subject being dealt with along with relevant figures and tables to visually show a clear picture of it. In all cases, detailed specifications of the instruments, subsystems, and systems have been included in addition to practical control loops and logistics to enable the book to be "all-time companion" for practicing engineers.

Discussions about both subcritical and super-ultra supercritical power plants, as well as IGCCs, have been included in order to take a look at future trends in power plants. Content keeps pace with development work in the field of electronics and control and communication engineering, with special attention to inclusion of the means and methods of system integration with fieldbus systems, OPC servers, and so on. Application of artificial intelligence and fuzzy logic in power plant instrumentation have been covered in detail.

In an attempt to incoporate this extensive subject area into the form of a book, the authors have carried out a great deal of research over years so as to include the knowledge gained during their decades-long global experience in thermal power plant instrumentation engineering. We wish to convey our sincere thanks to the companies who entrusted us to work in this specialized area of engineering. The authors feel rewarded only when their research work is able to benefit future engineers who can serve the global population by providing scarce pollution-free energy for human development.

**Swapan Basu**
**Ajay Kumar Debnath**

# Acknowledgments

At the outset, the authors wish to extend their gratitude to their professors of their engineering institution—Bengal Engineering College, Sibpore (now IIEST)—and their power plant and instrumentation gurus: the late Samir Kumar Shome (former DCL) and the late Makhan Lal Chakraborty (former DCL) for their great teaching in this area. The authors are extremely indebted to Dr. Shankar Sen (former professor at B. E.College) for his encouragement during development the book. While working on the book we were supported with information and suggestions of former colleagues D. K. Sarkar, J. K. Sarkar, D. J. Gupta, S. Chakraborty, A. Thakur, and Arijit Ghosh. In addition, we convey sincere thanks to friends: A. Bhattachariya (Kolkata), A. Sarkar (Norway), A. Tendulkar (Mumbai), N. Kirloskar (Pune), and S. Mohanty (Gurgaon) for their support and sharing of technical information. We would like to thank the authors of the works mentioned throughout the book and the Internet documents that stimulated and helped us write this book. The authors also like to thank the entire team of Systems & Controls Kolkata for infrastructural support. The authors would like to thank the entire team at Elsevier, the publisher, who took all the pains to bring it through to publication.

Last but not the least, we would like to thank our children Idai(Raj), Piku(Deb), Arijita, and Arijit for their continuous inspiration and support. A special thanks to our wives, Bani Basu and Syama Debnath, for managing the family show with care and for encouraging us so that we could dedicate time to the book. The authors sincerely acknowledge that without all these supports it would have been impossible to publish this book.

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Chapter I

# Introduction

## 1. INTRODUCTION

The authors of this book have been associated with the Instrumentation and Control System of Modern Power Plants for more than two decades while working with a leading consulting firm. They are still in touch with modern technology by associating with the engineering and consultancy activities of ongoing projects. We wanted to document their extended experience in the form of a reference book so that professional engineers, working engineers in power plants, and students could benefit from the knowledge gathered during their tenure.

There are so many valuable and good books available on a variety of subjects related to power plants about boilers, turbines, and generators and their subsystems, but it is very difficult to get a single book or single volume of a book to cater to the equipment, accessories, or items along with the instrumentation and control systems associated with them. In this book, there is a very brief description of the system and equipment along with diagrams for a cursory idea about the entire plant. Up-to-date piping and instrumentation diagrams (P&IDs) are included to better understand the tapping locations of measuring and control parameters of the plant.

Various types of instruments, along with sensors, transmitters, gauges, switches, signal conditioner/converter, etc., have been discussed in depth in dedicated chapters, whereas special types of instruments are covered in separate chapters. Instrument data sheets or specification sheets are included so that beginners may receive adequate support for preparing the documents required for their daily work.

The control system chapters VIII, IX and X incorporate the latest control philosophy that has been adopted in several power stations.

This book mainly emphasizes subcritical boilers, but a separate appendix is provided on supercritical boilers because of their economic and low-pollution aspects, which create a bigger demand and need than do conventional subcritical boilers.

It is hoped that this book may help students and/or those who perform power plant-oriented jobs.

## 2. FUNDAMENTAL KNOWLEDGE ABOUT BASIC PROCESS

Power plant concepts are based on the Laws of Thermodynamics, which depict the relationship among heat, work, and various properties of the systems. All types of energy transformations related to various systems (e.g., mechanical, electrical, chemical etc.) may fall under the study of thermodynamics and are basically founded on empirical formulae and system and/or process behavior. A thermodynamic system is a region in space on control volume or mass under study toward energy transformation within a system and transfer of energy across the boundaries of the system.

### 2.0 Ideas within and Outside the System

1. *Surrounding*: Space and matter outside the thermodynamic system.
2. *Universe*: Thermodynamic system and *surroundings* put together.
3. *Thermodynamic systems*:
    - **a.** *Closed*: Only energy may cross the boundaries with the mass remaining within the boundary.
    - **b.** *Open*: Transfer of mass takes place across the boundary.
    - **c.** *Isolated*: The system is isolated from its surrounding and no transfer of mass or energy takes place across the boundary.
4. *State*: It is the condition detailed in such a way that one state may be differentiated from all other states.
5. *Property*: Any observable characteristics measurable in terms of numbers and units of measurement, including physical qualities such as pressure, temperature, flow, level, location, speed, etc. The property of any system depends only on the state of the system and not on the process by which the state has been achieved.
    - **a.** *Intensive*: Does not depend on the mass of the system (e.g., pressure, temperature, specific volume, and density).
    - **b.** *Extensive*: Depends on the mass of the system (i.e., volume).



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6. *Specific weight*: The weight density (i.e., weight per unit volume).
7. *Specific volume*: Volume per unit mass.
8. *Pressure*: Force exerted by a system per unit area of the system.
9. *Path*: Thermodynamic system passes through a series of states.
10. *Process*: Where various changes of state take place.
11. *Cyclic process*: The process after various changes of state complete their journey at the same initial point of state.

## 2.0.1 Zeroeth Law of Thermodynamics

"If two systems are both in thermal equilibrium with a third system, they are in thermal equilibrium with each other." Thermal equilibrium displays no change in the thermodynamic coordinates of two isolated systems brought into contact; thus, they have a common and equal thermodynamic property called *temperature*. With the help of this law, the measurement of temperature was conceived. A thermometer uses a material's basic property, which changes with temperature.

### 2.0.1.1 Energy

"The definition in its simplest form is capacity for producing an effect." There are a variety of classifications for energy.

1. Stored energy may be described as the energy contained within the system's boundaries. There are various forms, such as:
   a. Potential
   b. Kinetic
   c. Internal
2. Energy in transition may be described as energy that crosses the system's boundaries. There are various types, such as:
   a. Heat energy (thermal energy)
   b. Electrical energy
   c. Work

### 2.0.1.2 Work

"Work is transferred from the system during a given operation if the sole effect external to the system can be reduced to the rise of a weight." This form of energy is transferred from one system to another system originally at different temperatures. It may take place by contact and without mass flow across the boundaries of the two systems. This energy flows from a higher temperature to a lower temperature and is energy in transition only and not the property. The unit in the metric system is kcal and is denoted by $Q$.

### 2.0.1.3 Specific Heat

Specific heat is defined as the amount of heat required to raise the temperature of a substance of unit mass by one degree. There are two types of specific heat:

1. At constant pressure and denoted as $Cp$
2. At constant volume and denoted as $Cv$

Heat energy is a path function and the amount of heat transfer can be given by the following:

$${}_1Q_2 = \text{Integration from } T_1 \text{ to } T_2 \text{ of } m\,Cn\,dT,$$

$$\text{i.e., } \int_{T_1}^{T_2} (m\,Cn\,dT),$$

where 1 and 2 are two points in the path through which change takes place in the system, $m$ is the mass, $Cn$ is the specific heat and maybe $Cp$, $dT$ is the differential temperature, and $T_1$ and $T_2$ are the two temperatures at point 1 and 2 of the path.

### 2.0.1.4 Perfect Gas

A particular gas that obeys all laws strictly under all conditions is called a *perfect gas*. In reality no such gas exists; however, but by applying a fair approximation some gases are considered as perfect (air and nitrogen) and obey the gas laws within the range of pressure and temperature of a normal thermodynamic application.

## 2.0.2 Boyle's Law and the Charles Law

### 2.0.2.1 Boyle's Law—Law I

The volume of a given mass of a perfect gas varies inversely as the absolute pressure when temperature is constant.

### 2.0.2.2 Charles Law—Law II

The volume of a given mass of a perfect gas varies directly as the absolute temperature, if the pressure is constant.

## 2.0.3 General and Combined Equation

From a practical point of view, neither Boyle's Law nor the Charles Law is applicable to any thermodynamic system because volume, pressure, and temperature, etc., all vary simultaneously as an effect of others. Therefore, it is necessary to obtain a general and combined equation for a given mass undergoing interacting changes in volume, pressure, and temperature:

$$v \propto T/p, \text{ when } T \text{ is constant (Boyle's Law)}$$

$$v \propto T, \text{ when } p \text{ is constant (Charles Law).}$$

Therefore, $v \propto T/p$ when both pressure and temperature vary