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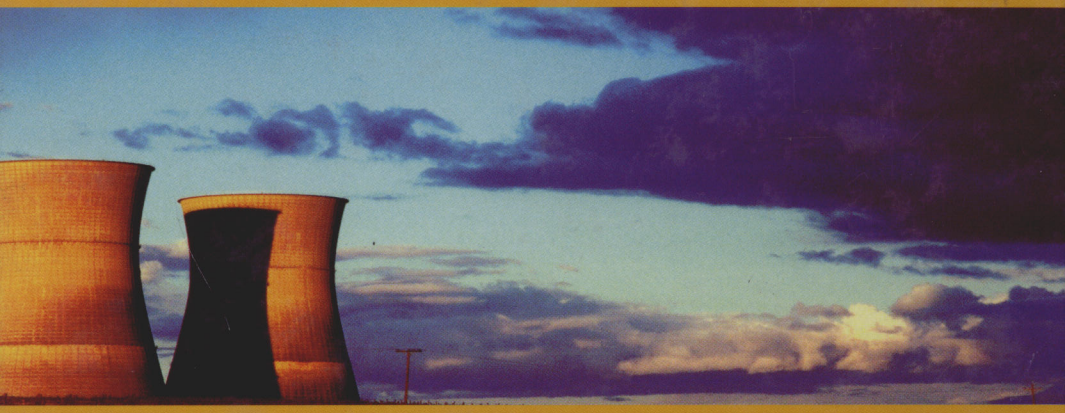

Thermal Power Plant Simulation and Control

Edited by Damian Flynn

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Preface

During the past decade power generation has undergone several extremely significant changes. These include deregulation of the electricity industry in many parts of the world, with a greater focus on economic and financial concerns instead of purely engineering issues. In conjunction with this, environmental matters are of increasing interest, leading to an assessment of existing greenhouse gas emissions and the exploitation of renewable energy sources. Additionally, combined cycle gas turbines (CCGTs) have emerged as an extremely economic and efficient means of electricity generation. Finally, many power plants have been retro-fitted with modern and sophisticated, plant-wide instrumentation and control equipment. These computer-based distribution control systems (DCSs) are intended to enhance regulation control performance and more importantly provide a means for implementing supervisory control/monitoring schemes.

These various considerations have led to significant changes in the philosophy of how power stations are operated, while at the same time affording engineers the opportunity to introduce monitoring and plant-wide control schemes which were previously infeasible. However, a distinction has largely arisen between those working in the power and control oriented research communities, with centres of excellence in scattered locations, and engineers engaged in power plant design, operation, consultancy, etc. The objective of this book is to address this issue, through a number of case studies, which illustrate how various methodologies can be applied to various subsystems of power plant operation, or indeed introduced into the overall control hierarchy. The case studies presented focus on what can feasibly be achieved with an indication of the subsequent benefits of doing so, using results from live plant where possible.

The level of the book makes it suitable for engineers working in the power generation industry who wish to gain an appreciation of the advances which have taken place in this field within the research community. It should also provide a very useful overview for new and experienced researchers working in this area. A number of the contributions to this book arise from work carried out at, or in collaboration with, universities and research institutions, while others benefit from the experience of practitioners in the industry. A natural consequence of this is that a mixture of viewpoints is offered, with a contrast between the use of academic and industrial

terminology. The mathematical content of the book is sufficient to give an indication of the underlying technologies, and the deficiencies of more traditional techniques, with the reader directed to related work for further detail.

The text is split into three main parts covering, respectively, power plant simulation, specific control applications and optimisation/monitoring of plant operations. Chapter 1 provides a brief introduction to power plant fundamentals, outlining different plant configurations, the control requirements of various loops, and the hardware and instrumentation on which these systems are based. An essential aspect of investigating and developing novel control and monitoring schemes is a detailed simulation of the system in question. Chapter 2 illustrates how a complex power plant model can be constructed using an object-oriented approach. The reader is introduced to the Modelica modelling language, and issues such as testing and validation are discussed.

Part 2 (Control) comprises five contributions and forms a major part of the book. A number of diverse applications are considered, and differing control strategies are proposed and implemented. Chapter 3 investigates the highly complex problem of both modelling and controlling pulverised fuel coal mills. Linear quadratic and predictive control techniques are investigated, with a supervisory operator support system introduced. Chapter 4 tackles the problem of excitation control of a synchronous machine. Local model network and adaptive control-based approaches are examined in detail. Chapter 5 then examines steam temperature control of a once-through boiler for both the evaporator and superheaters. Linear quadratic Gaussian, fuzzy logic and predictive control schemes are applied, with the benefits of feedforward action using suitable instrumentation strongly highlighted. Chapter 6 examines the problem of controlling combined cycle plant. An objective function is defined based on operational costs, and alternative hierarchical control configurations are examined. Finally, in this section, Chapter 7 explores the development of a multi-input multi-output (MIMO) predictive controller sitting on top of the plant's conventional control systems to improve the overall plant's capabilities.

Part 3 (Monitoring, optimisation and supervision) again comprises five contributions, and demonstrates how the ability of distributed control systems to gather plant-wide, real-time data can be constructively employed in a range of applications. Chapter 8 introduces a sophisticated plant-wide, neurofuzzy control scheme with feedback and feedforward actions to provide improved unit manoeuvrability and an improved distribution of control tasks. Chapter 9 then focuses on the task of modelling NO_x emissions from a coal-fired power station. A grey-box modelling approach is proposed, taking advantage of a priori knowledge of NO_x formation mechanisms. Chapter 10 introduces model-based approaches for fault detection of a high-pressure heater line. Again grey-box identification, coupled with non-linear state estimation techniques are considered, to aid fault diagnostics. Chapter 11 continues with an examination of how the data stores which distributed control systems now offer can be exploited for both fault identification and process monitoring activities. The part concludes in Chapter 12 with an overview of a number of performance support and monitoring applications that have been successfully applied to real plant, largely based around a real-time expert system.

The final part of the book highlights some possibilities and issues for the future. Chapter 13 demonstrates how a physical model of a power plant can be integrated into a predictive control strategy to provide enhanced unit control by recognising the true system characteristics. Finally, Chapter 14 discusses some topics of concern including the impact of age and maintenance requirements on existing units in an increasingly competitive environment, and how technology is expanding the capabilities of modern power plant.

The editor would like to take this opportunity to thank all the authors for their contributions, and for their assistance in bringing together the final text. The support and guidance from Roland Harwood and Wendy Hiles of the IEE has also been most welcome. The editor also wishes to acknowledge the significant role played in the creation of this work by Brian Hogg and Edwin Swidenbank in establishing the Control of Power Systems research group at The Queen's University of Belfast. Finally, the advice and encouragement offered by Brendan Fox and Nataša Martać from Queen's has been greatly appreciated.

Damian Flynn
April 2003

List of abbreviations

AF	availability factor
ANN	artificial neural network
API	application program interface
APMS	advanced plant management system
ARMAX	AutoRegressive Moving Average model with eXogenous input
ARX	AutoRegressive model with eXogenous input
ASME	American Society of Mechanical Engineers
AVA	added value application
AVR	automatic voltage regulator
BETTA	British-wide Electricity Trading and Transmission Arrangements
BMS	burner management system
CARIMA	controlled auto-regressive integrating moving-average
CBR	case-based reasoning
CCGT	combined cycle gas turbine
CCR	central control room
CEGB	Central Electricity Generating Board
CFD	computational fluid dynamics
COL	cost of losses
DCDAS	distributed control and data acquisition system
DCS	distributed control system
DMA	direct memory access
EAF	equivalent availability factor
EC	European Commission
EDL	electronic dispatch and logging
EKF	extended Kalman filter
EPRI	Electric Power Research Institute
FB	feedback
FERC	Federal Energy Regulatory Commission
FF	feedforward
FFPU	fossil fuel power unit
FGD	flue gas desulphurisation
GHG	greenhouse gas

GMV	generalised minimum variance
GPC	generalised predictive control
HMI	human–machine interface
HP	high-pressure
HRSG	heat recovery steam generator
HSC	hierarchical supervisory control
IAF	integrated application framework
ICOAS	intelligent control and advisory system
IGCC	integrated gasification combined cycle
ILC	integrated load control
ILM	integrated load management
IOAS	intelligent operator advisory system
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
ISA	Instrumentation, Systems and Automation Society
KBOSS	knowledge-based operator support system
LMN	local model network
LP	low-pressure
LPC	lumped parameter components
LQ	linear quadratic
LQG	linear quadratic Gaussian
LQR	linear quadratic regulator
LS	least squares
MBPC	model-based predictive controller
MCR	maximum continuous rating
MIMO	multi-input multi-output
MISO	multi-input single-output
MLP	multilayer perceptron
MLR	multiple linear regression
MVC	multivariable steam control
NARMAX	Non-linear AutoRegressive Moving Average model with eXogenous input
NARX	Non-linear AutoRegressive model with eXogenous input
NDE	non-destructive evaluation
NETA	New Electricity Trading Arrangements
NIPALS	non-linear iterative partial least squares
NPMPC	non-linear physical model-based predictive control
OIS	operational information system
OOM	object-oriented modelling
OSC	one-side components
PCA	principal component analysis
pf	pulverised fuel
PFBC	pressurised fluidised bed combustion
PLC	programmable logic controller

PLS	projection to latent structures
PRBS	pseudo-random binary sequence
PRESS	predicted residual sum of squares
RBF	radial basis function
RLS	recursive least squares
RMS	root mean square
RSME	root squared mean error
SCADA	supervisory control and data acquisition
SEGPC	state estimation-based generalised predictive control
SISO	single-input single-output
SMS	startup management system
TSC	two-side components
UV	ultraviolet
VOC	volatile organic compound

Contents

Part 2: Control

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