ENERGY SCIENCE AND ENGINEERING: RESOURCES, TECHNOLOGY, MANAGEMENT
AN INTERNATIONAL SERIES

COMPUTER-BASED ENERGY MANAGEMENT SYSTEMS

Technology and Applications

CHUN H. CHO

Computer-Based Energy Management Systems

Technology and Applications

CHUN H. CHO
Fisher Controls International, Inc.
Marshalltown, Iowa

1984

ACADEMIC PRESS, INC.
(Harcourt Brace Jovanovich, Publishers)
Orlando San Diego New York London
Toronto Montreal Sydney Tokyo

ACADEMIC PRESS, INC.
Orlando, Florida 32887

United Kingdom Edition published by
ACADEMIC PRESS, INC. (LONDON) LTD.
24/28 Oval Road, London NW1 7DX

Library of Congress Cataloging in Publication Data

Cho, Chun H.
Computer-based energy management systems.

(Energy science & engineering)
Includes index.
1. Industry--Energy conservation--Data processing.
I. Title. II. Series: Energy science and engineering.
TJ163.3.C46 1984 658.2'6 83-22341
ISBN 0-12-173380-7 (alk. paper)

PRINTED IN THE UNITED STATES OF AMERICA

84 85 86 87 9 8 7 6 5 4 3 2 1

Computer-Based Energy Management Systems

Technology and Applications

ENERGY SCIENCE AND ENGINEERING:
RESOURCES, TECHNOLOGY, MANAGEMENT
An International Series

EDITOR
JESSE DENTON
Belton, Texas

LARRY L. ANDERSON and DAVID A. TILLMAN (eds.), Fuels from Waste, 1977

A. J. ELLIS and W. A. J. MAHON, Chemistry and Geothermal Systems, 1977

FRANCIS G. SHINSKEY, Energy Conservation through Control, 1978

N. BERKOWITZ, An Introduction to Coal Technology, 1979

JAN F. KREIDER, Medium and High Temperature Solar Processes, 1979

B. SØRENSEN, Renewable Energy, 1979

J. H. HARKER and J. R. BACKHURST, Fuel and Energy, 1981

STEPHEN J. FONASH, Solar Cell Device Physics, 1981

MALCOLM A. GRANT, IAN G. DONALDSON, and PAUL F. BIXLEY, Geothermal Reservoir Engineering, 1982

W. F. KENNEY, Energy Conservation in the Process Industries, 1984

CHUN H. CHO, Computer-Based Energy Management Systems: Technology and Applications, 1984

To Max and Jean Billinger

For the encouragement and inspiration that allowed me to advance my educational goals and career

Preface

The era of low-cost energy is undoubtedly a thing of the past. Today, energy management in industry is more than a fashionable subject, it is an outright necessity. The objective of an energy management system is simple enough to understand, but the means of improving plant energy efficiency is usually not so obvious.

Since the oil embargo of 1973, a major effort has been initiated by many energy-intensive process industries, as well as managers of large institutional buildings, to reduce energy consumption using the 1972 energy usage rates and costs as a base case.

It is generally true that from 1973 to 1975 most of the easily obtainable savings requiring low capital investments for energy conservation were achieved. These savings were mainly in the area of long-neglected housekeeping practices, for example, developing better insulation for steam pipes, starting steam trap maintenance programs, lowering thermostats, preventing steam leaks, and upgrading instrumentation for utility generation–distribution systems. Today, energy-intensive industries such as pulp and paper, petrochemical, and food processing are focusing their efforts on identifying, justifying, and implementing energy management systems to meet corporate mandates of 10–15% energy reduction per unit of production in addition to the 10–20% savings already realized since the embargo of 1973.

The trend is definitely toward a computer-based energy management system whose size will depend on the complexity of the utility complex. Computer technology has made major advances during the past 10–15 years. As a result, energy management and process control applications in many process industries are becoming more attractive because of the increasing reliability and decreasing cost of computer hardware. There have been significant activities both by users and manufacturers in the development and application of many pieces of software for controlling and optimizing utility complex and process unit operations.

The intent of this book is to present the material that is pertinent to planning, organizing, and developing computer-based energy management systems for industrial plants. The concepts, philosophical dissertations, and methodologies are developed and documented in such a way that readers can identify, select, and tailor their use of the book with respect to the specific needs of their plant.

Chapters 1–4 are devoted to giving the reader a good understanding of the concepts of computer-based energy management systems, approaches, and trends. In addition, the benefits of implementing advanced controls by upgrading plant instrumentation are highlighted in Chapter 2.

A comprehensive review of optimization techniques is included in Chapter 3, with particular emphasis on the techniques that can be readily adapted to solve complex energy allocation problems. These techniques have been available for many years, but until now we lacked the ability to apply them to engineering problems. In recent years, due to the availability of the process control computer, we have been able to handle optimization problems in an economical and timely manner so that real-time decisions can be made in the operation of a plant utility complex.

A thorough review of specifying and selecting a computer system is given in Chapter 4, from a user's as well as a supplier's point of view. Because of the tremendous proliferation of computer systems in the marketplace, it is no easy task to go about selecting a computer system that satisfies all of your functional requirements in both hardware and software. To a large extent, the success of a project depends on selecting the right computer and a supplier who can provide the necessary support.

Chapters 5–8 focus on the major utilities in process plants with respect to specific energy-savings potential and related computer functions. Steam, electric power, and refrigeration generally account for most of the plant energy budget. Computer systems have been playing a major role in reducing the consumption of such utilities.

Chapter 9 includes a summary of energy management opportunities in six selected industries: pulp and paper, steel, refining, chemical, textile, and energy production. The major differences in energy-savings potential among these industries are due to the process operations unique to each industry. The horizontal technology, as related to the basic utility systems discussed in Chapters 5–8, generally cuts across the boundaries of process operations.

A plant study to develop economic justification for a proposal is the single most important step toward competing for capital expenditures. Chapter 10 is intended to give the reader some ideas for analyzing plant data and developing a sound, documented basis for a potential energy savings.

This book covers a wide range of energy management topics and can be used to introduce practicing engineers to the field, to teach short courses in industrial energy systems, and as a reference book. In addition, the book should prove to be very beneficial as a supplementary reference book for undergraduate and graduate students in energy systems curricula. Because many of the optimization techniques mentioned in this book can be enhanced or need alternative solutions, it may spark further research ideas and developments in software applications.

List of Symbols

a, b, c	Constants
A	Surface area
β	Beta ratio
BD	Blowdown
C	Constant, Cost
C_d	Discharge coefficient
COP	Coefficient of performance
C_t	Operating cost
C_p	Specific heat of water
CNF	Configuration function
D	Demand
DSP	Desuperheating
ε	Efficiency
F	Fuel flow rate
FT	Flow transmitter
G_c	Generation cost
I	Ideal
H	Enthalphy
ΔH	Change in enthalphy
h_{fd}	Convective heat-transfer film coefficient
HR	Actual heat rate
h_s	Scale heat-transfer coefficient
K	Fuel cost
K_c	Compressor input energy
K_p	Pumping-cost factor for condenser
L	Load
LT	Level transmitter
M	Maximum value
M	Total mass of combustion product
M_c	Cooling-water flow
M_e	Chilled-water flow
MDC	Master demand controller
N	Number of stages
OE	Operating expense
P	Pressure
P_{fc}	Condenser-head pressure
PC	Pressure controller
PLC	Programmable logic controller
Q	Condenser heat load, Gas flow
Q_s	Mass flow rate of steam
ROI	Return on investment
S	Steaming rate, Scale factor
SC	Steam cost
ΔT_c	Condenser temperature differential
ΔT_e	Temperature differential across evaporator
U	Heat-transfer coefficient
VPC	Valve position controller
W_s	Compressor supplied energy
$\bar{x}$	n-dimensional vector
X	Fraction of excess air
Y	Mole fraction
Y_a	Adiabatic expression factor
Θ_m	Log-mean temperature difference
ρ	Density
λ	Arbitrary multiplier

Contents

3
Optimization Techniques

4
Selecting Computer Systems

5
Steam Plant Management

6
Electrical Power Management

7
Refrigeration Management Systems

8
Energy Accounting and System Diagnostics

9
Energy Management Opportunities in Selected Process Industries

10
Plant Study Procedures for Energy Conservation Projects

1

Introduction

The most easily obtainable benefits requiring low capital investments for energy conservation have already been achieved by the energy-intensive industries since the oil embargo of 1973. In recent years computer-based energy management systems have played an increasingly important role in plantwide energy allocation and optimization to reduce production costs. Computer systems allow utility engineers to access real-time operating and performance information for energy-intensive equipment such as boilers, turbogenerators, compressors, and chillers and to optimize and control these systems to improve and maintain their energy utilization efficiencies. The application of computer systems also extends to many steam users, both in steam distribution systems and process areas.

A. Energy Management Activities and Approaches

Energy management activities include upgrading instrumentation to improve the efficiency of energy conversion efforts, optimizing load allocation, optimizing utility distribution, optimizing the allocation of fuels, managing electrical power and in-plant generation, and improving the energy efficiency of unit operations.

Successful energy management with computer systems requires careful planning and definition of each area included in the system with respect to the specific objective to be achieved. Every energy management project needs well-defined objectives and logical steps. The following guidelines may satisfy these needs.

(1) Identify and define the areas where energy management opportunities exist.
(2) Determine system functions and hardware and software requirements for each area.
(3) Make a cost–benefit analysis for the selected area of application. This phase is critical because a realistic savings projection is necessary to satisfy capital expenditure or return-on-investment (ROI) criteria. Such savings projections can be made by analyzing plant utility operating data or, in the absence of utility logs, by making a best engineering estimate.
(4) Prioritize the implementation plan based on the payback period of each application area.
(5) Make a plan to track the performance of and evaluate the energy management system in terms of cost savings upon system implementation.
(6) Select the system so that it can be expanded to integrate future energy systems.

B. Computer Functions

At the time the system specifications are developed it is important to focus on the following segments of the computer applications as applied to a given plant and its needs (Cho, 1975):

(1) data acquisition, calculation, and display;
(2) control philosophy and procedures [e.g., supervisory versus direct digital control (DDC), including backup requirements];
(3) identification of trends in plant data and performance variables;
(4) optimization techniques and procedures;
(5) logs and alarms; and
(6) management information systems.

There are many other concerns about the digital system that should be carefully evaluated in the course of the computer selection process (see Chapter 4).

C. System Implementation

Once the computer system specification is developed for energy management, there are several issues that should be addressed and clearly defined within the context of plant engineering expertise and available manpower. The major elements needing to be addressed at the time of project definition are design base and system specifications, system engineering, system integration, installation, and checkout, system startup and service, manufacturer-supplied software, custom software, spare parts, documentation, and costs.

D. Energy Conservation Opportunities

Most process industries, such as the petrochemical, pulp and paper, refining, and textile industries, use steam, electricity, cooling water, chilled water, compressed air, and many other forms and levels of utilities to process their products. Energy conservation opportunities generally exist in three areas in each utility energy system: generation, distribution, and consumption.

1. GENERATION

Steam, electricity, chilled water, and compressed air are generally either produced in the plant or purchased from outside utilities. Therefore, potential savings exist that may be obtained by minimizing the consumption of fuel or electricity in the generation of these utilities. It is not unusual to allocate as much as 60% of the cost of purchased fuel for steam generation and 20–30% for electrical power, either purchased or generated in-plant. In general, steam and/or electrical power must be consumed to generate chilled water, cooling tower water, compressed air, and many other utilities at the desired level of quality.

2. DISTRIBUTION

The distribution of generated energy is an extremely important factor in energy management systems. The objective of a distribution system is to deliver the required quantity and quality of energy to users without altering its original characteristics. Pressure, temperature, flow rate, and composition are a few of the essential elements that, depending on the type of utility, must be maintained to satisfy user specifications.

3. CONSUMPTION

The opportunity for saving energy is greater in the process that *uses* the utility. However, this is also the most difficult area for obtaining immediate results, because it requires an in-depth study to ensure that the conservation program would not interfere with the plant yield and product quality.

Many conservation opportunities exist in the area of by-product recovery. In many industries recovered and recycled heat energy constitute an important energy source and an opportunity for fuel conservation. The American Paper Institute reports that 20% of the energy needed to make pulp and paper is obtained from the burning and recycling of spent pulping liquid; an additional 8% of the required process steam is provided by the use of wood waste as fuel.