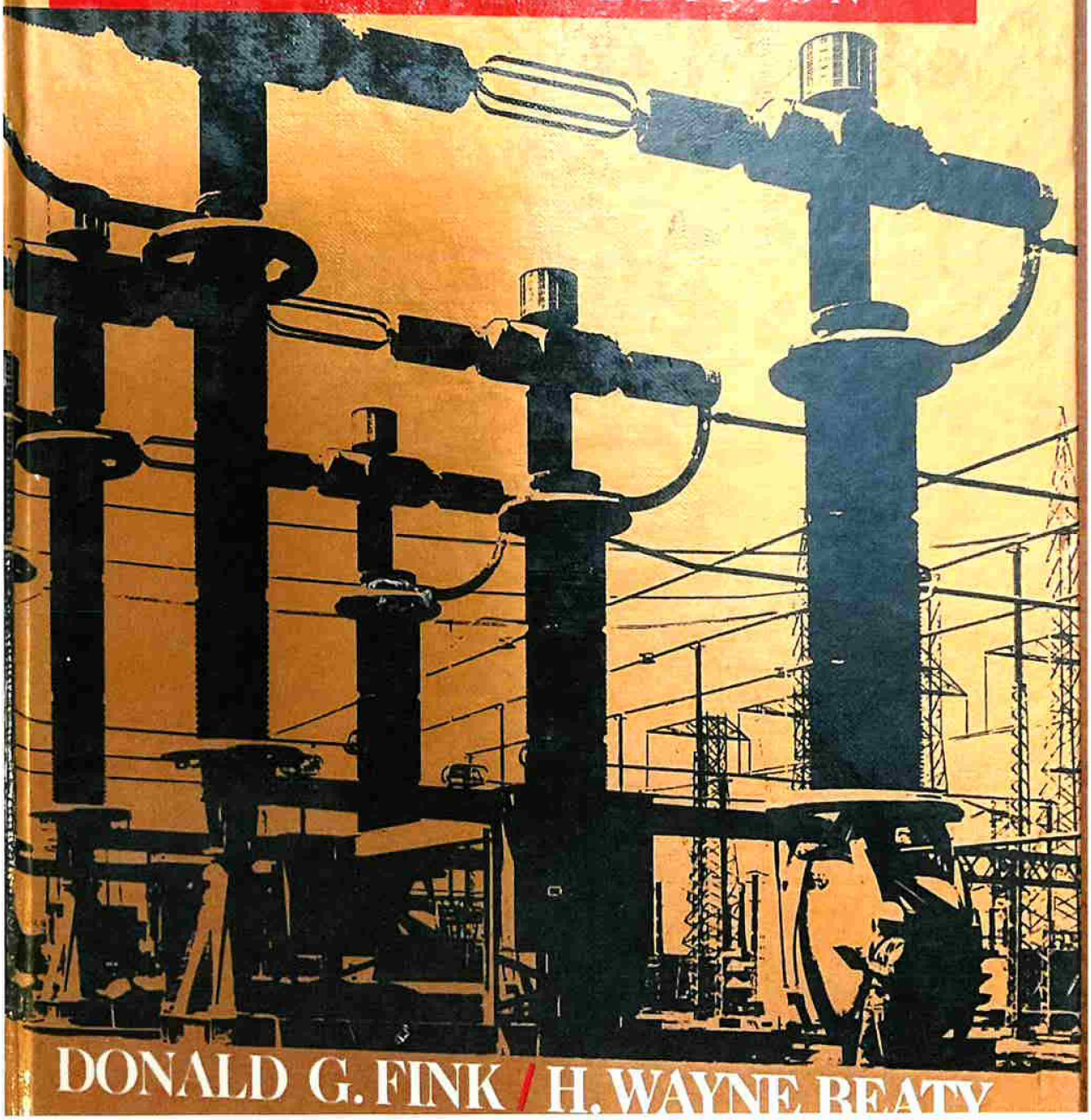
STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

THIRTEENTH EDITION



DONALD G. FINK / H. WAYNE BEATY

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS



Other Electrical Power Engineering Books of Interest

Cadick · ELECTRICAL POWER SYSTEMS SAFETY HANDBOOK
Denno · ELECTRIC PROTECTIVE DEVICES
Kundur · POWER SYSTEM STABILITY AND CONTROL
Kurtz & Shoemaker · THE LINEMAN'S AND CABLEMAN'S HANDBOOK
Kusko · EMERGENCY/STANDBY POWER SYSTEMS
Linden · HANDBOOK OF BATTERIES AND FUEL CELLS
Lundquist · ON-LINE ELECTRICAL TROUBLESHOOTING
Miller & Malinowski · POWER SYSTEM OPERATION
Pete · ELECTRIC POWER SYSTEMS MANUAL
Seidman, Mahrous, & Hicks · HANDBOOK OF ELECTRIC POWER CALCULATIONS
Smeaton · SWITCHGEAR AND CONTROL HANDBOOK
Taylor · POWER SYSTEM VOLTAGE STABILITY
Wang & MacDonald · MODERN POWER SYSTEM PLANNING

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

Donald G. Fink Editor

Director Emeritus, Institute of Electrical and Electronics Engineers; formerly Vice President—Research, Philco Corporation; President of the Institute of Radio Engineers; Editor of the Proceedings of the IRE; Fellow of the IEEE; Fellow of the IEE (London); Eminent Member, Eta Kappa Nu; Member of the National Academy of Engineering

H. Wayne Beaty Editor

Managing Editor, Electric Light and Power; Editorial Director, Power Delivery Product News; Former Vice President, Loadmaster Systems, Inc.; Former Senior Editor, Electrical World; Senior Member of the Institute of Electrical and Electronics Engineers

Thirteenth Edition

McGRAW-HILL, INC.

New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto

The Library of Congress cataloged the First Issue as follows:

Standard handbook for electrical engineers. 1st- ed.
v, diagrs., tables. 18–24 cm.
Editors: 4th–6th, F. F. Fowle.—7th- A. E. Knowlton
1. Electric engineering—Handbooks, manuals, etc.
I. Fowle, Frank Fuller, date, ed. II. Knowlton, Archer Eben, date, ed.
TK151.S8 56-6964
Library of Congress [r58n³19]
ISBN 0-07-020975-8

Copyright © 1993, 1987, 1978, 1968, 1957 by McGraw-Hill, Inc. All Rights Reserved.

Copyright renewed 1985, 1977, 1969, 1961, 1950, 1943, 1936, 1935 by McGraw-Hill, Inc. All Rights Reserved.

Copyright 1949, 1941, 1933, 1922, 1915, 1910, 1908, 1907 by McGraw-Hill, Inc. All Rights Reserved
Printed in the United States of America. Except as permitted under the United States Copyright Act of 1976, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a data base or retrieval system, without the prior written permission of the publisher.

3 4 5 6 7 8 9 0 DOC DOC 9 9 8 7 6 5 4

ISBN 0-07-020984-7

The sponsoring editor for this book was Harold B. Crawford, the editing supervisor was Nancy Young, and the production supervisor was Suzanne W. Babeuf. This book was set in Times Roman by Progressive Typographers, Inc.

Printed and bound by R. R. Donnelley & Sons Company.

Information contained in this work has been obtained by McGraw-Hill, Inc., from sources believed to be reliable. However, neither McGraw-Hill nor its authors guarantees the accuracy or completeness of any information published herein and neither McGraw-Hill nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that McGraw-Hill and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

CONTENTS

Contributors to the Thirteenth Edition ix
Preface to the Thirteenth Edition xiii

Section 1. Units, Symbols, Constants, Definitions, and Conversion Factors 1-1

SI units and conversion factors; prefixes and usage; definitions of quantities; letter and graphic symbols; physical constants and numerical values

Section 2. Electric and Magnetic Circuits 2-1

Action and reaction of charge; potential; current; electric and magnetic fields in circuits; forces; losses; steady-state and transient effects; filter design by insertion loss method

Section 3. Measurements and Instruments 3-1

Principles and equipment for measuring electric, magnetic, mechanical, thermal, and other nonelectric quantities; telemetry; measurement errors

Section 4. Properties of Materials 4-1

Conductors; magnetic materials; insulating materials; structural materials

Section 5. Generation 5-1

Fossil-fueled steam generation; nuclear-fueled steam generation; nuclear power for the future; circulating water systems and components

Section 6. Prime Movers 6-1

Steam engines and turbines; steam turbine applications; steam turbine performance; control and protective systems; lubrication and hydraulic systems; gas turbines

Section 7. Alternating-Current Generators 7-1

Magnetic circuits; field and armature design; insulation; cooling; mechanical construction; transient effects; losses and efficiencies; test methods

LIBERTY EXHIBIT 1040, Page 6

Section 8. Direct-Current Generators 8-1

General principles; armature windings; reactions and design; commutation; compensating fields; main field; cooling; losses and efficiencies; characteristics; testing and maintenance; special dc generators

Section 9. Hydroelectric Power Generation 9-1

Hydraulic turbines; elements of a hydroelectric plant; power plant settings; design factors; efficiency performance; reversible pump turbines; model tests; speed control; cavitation

Section 10. Power-System Components 10-1

Transformer theory, connections, design, insulation, testing, loading practices; circuit breaker principles, design, and operation; metal-clad switchgear; voltage regulators; methods of regulation; power capacitor application and principles; line drop compensation; fuses, switches, molded-case breakers, and buses

Section 11. Alternate Sources and Converters of Power 11-1

Solar power; geothermal power; wind power; energy storage methods; magnetohydrodynamics; nuclear fusion; thermoelectric and thermionic conversion; batteries and fuel cells

Section 12. Economics of Bulk Electric Power Supply 12-1

Primary sources of power; energy storage systems; by-product power; fuels; development of overall costs; reserve capacity; reliability; availability; capacity factor; load factor; generating capacity mix; interconnection and pooling

Section 13. Project Economics 13-1

Bottom-line economic measurements; value of money; decision criteria; after-tax cash flows; financing effects; leasing; rate-of-return requirements; investments; risk and reward

Section 14. Transmission Systems 14-1

Overhead ac power transmission; economics; electrical properties of conductors; system stability; corona, audible noise, and ozone; line insulation; mechanical designs; operation and maintenance; underground transmission systems; cable systems; electrical characteristics; installation methods; accessories; future developments

Section 15. Direct-Current Power Transmission 15-1

Converter behavior; terminal design; filters; system protection; switching; subsynchronous oscillations; overhead lines and cables; valves; transformers and reactors; breakers; testing; operation and maintenance

Section 16. Power-System Operations 16-1

Control of generation and power flow; schedule deviations; economic dispatch; control application; power system security; relaying and protection; power-line carrier; carrier current; carrier communication; carrier relaying

Section 17. Substation Design 17-1

Voltage levels; bus types and connections; reliability comparisons; physical arrangements; support structures; clearances; protective relaying; transformer protection; grounding; loading practices

Section 18. Power Distribution 18-1

Classification and application of distribution systems; calculation of voltage regulation and losses; voltage control; overcurrent protection; overvoltage protection; transformers; capacitors; secondary systems; underground systems; economics; street lighting systems; subtransmission system

Section 19. Wiring Design for Commercial and Industrial Buildings 19-1

Rules and inspection; methods of wiring; types of conductors and circuits; protection and control; grounding; standards for commercial, public, and industrial structures; procedures for designing wiring for lighting, motor loads, space heating, and primary-supply systems; circuit and conductor calculations; economics; low-voltage busway

Section 20. Motors and Drives 20-1

Direct-current motors; synchronous motors; induction machines; testing of polyphase induction machines; design characteristics; single-phase induction machines; ac commutator motors; fractional-horsepower motors; motor control; starting devices; stopping devices; motor protecting devices

Section 21. Industrial and Commercial Applications of Electric Power 21-1

Applications in the following areas: petroleum industry; steel mills; agriculture; coal mines; electric elevators; numerical control; air conditioning and refrigeration

Section 22. Electronics 22-1

Inverters; power-frequency changers; industrial electronics; solid-state devices; integrated circuits; microprocessors; microcomputers; transducers; relays; uninterruptible power supplies; lasers; security equipment

Section 23. Power Quality 23-1

Effects of power quality on equipment; types of problems; site surveys; electrical system design; investigative techniques; power conditioning equipment

Section 24. Electrochemistry and Electrometallurgy 24-1

Electrolytes; electrode reactions; current and voltage relationships; galvanic cells; electrodeposition; electrolytic refining; electrowinning; electrosynthesis; batteries; fuel cells; corrosion

Section 25. Computer Applications in the Electric Power Industry 25-1

Goals of power industry management; current computer applications in power system planning; systems operation; plant monitoring and control; design; construction; environmental considerations; future computer applications

Section 26. Illumination 26-1

Units, factors, and standards of radiant energy and light; incandescent lamps; mercury and glow lamps; electroluminescent lamps; fluorescent lamps; luminaires and lighting fixtures; accessories and fixtures; illumination calculations; flood lighting; detectors and photometry; colorimetry and spectrophotometry; economics and maintenance

Section 27. Lightning and Surge Protection 27-1

Fundamentals; comparison of silicon carbide and metal-oxide arresters; arrester classes; insulation coordination; selection of arresters; modeling

Section 28. Standards in Electrotechnology 28-1

History of standards; standards and the law; voluntary standards system; terminology in standards; organizations concerned with electrical standards; government regulatory standards bodies; International Electrotechnical Commission; alphabetical list of electrical standards by subject matter

Index follows Section 28