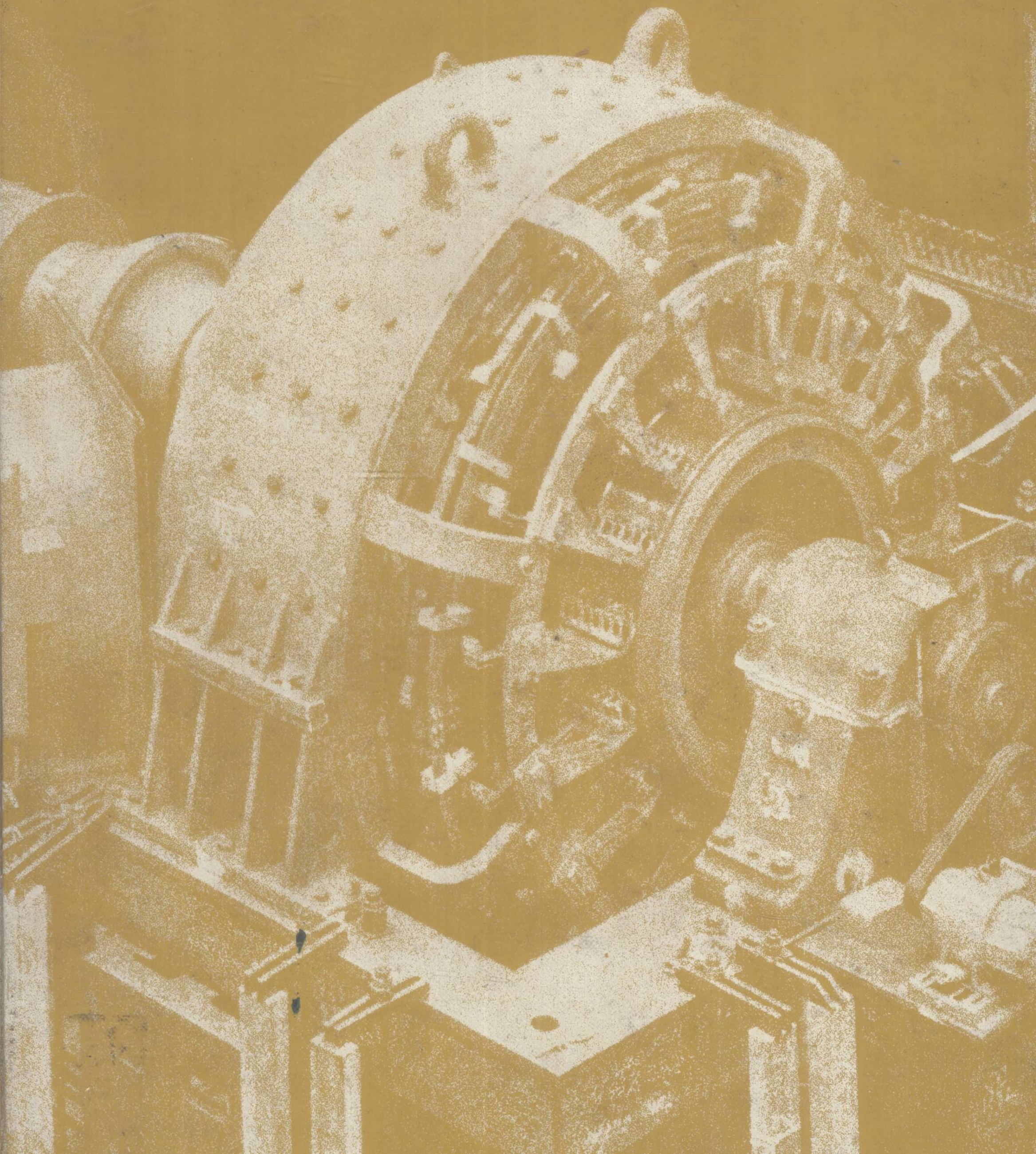
ELECTRIC MACHINERY AND TRANSFORMERS

IRVING L. KOSOW



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IRVING L. KOSOW, PH.D.

Staten Island Community College
City University of New York

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ELECTRIC MACHINERY AND TRANSFORMERS

To my wife

RUTH

and my children

SONIA, MARTIN, and JULIA

preface

This work is an outgrowth of the author's earlier *Electric Machinery and Control*, originally published in 1964. In revising, supplementing and updating that work, it became clear that two volumes were necessary to present the material properly and keep pace with the state-of-the-art. A variety of reasons dictated this choice. The original work was already fairly large (over 700 pages) and the contemplated new material would inevitably result in a most unwieldy and expensive volume.

A logical division between electric machinery theory and control applications of electric machinery already exists in the literature. Numerous works already exist in separate volumes in these areas, so there is a precedent for such a dichotomy. The student who requires a background in the theory of electric machines and their characteristics should be introduced to the subject in a way that is different from that required by the practicing engineer and technician in the field. The latter, primarily, are interested in the control and commercial applications of electric machinery covered in the second volume, although reference to this first volume may occasionally be required.

This first volume, therefore, is a text which reflects the feedback from teachers and students who used the earlier *Electric Machinery and Control.* In response to numerous requests, a new chapter on Transformers has been added. In addition, questions have been added to each chapter to sharpen the reader's qualitative comprehension of the material. The language of the text has been rewritten, in part, to clarify important theoretical distinctions, facilitate comprehension, and more importantly, to enable self-study. New problems and illustrative examples have been added. Unit abbreviations have been revised to reflect IEEE standards.

The earlier rationale for the study of electric machinery cited in the preface of *Electric Machinery and Control* has been accentuated by two major worldwide problems: pollution (of our lands, waters and atmosphere) and overpopulation. The latter has resulted in tremendously increased demands for power and personalized transportation, along with consumer goods of a wide variety, concomitant with a rising standard of living, and this inevitably has produced the former. As a consequence, engineers and scientists are taking a new look at electric power generation, energy conversion, and the use of electrical (pollution free or relatively low pollution) traction techniques for rail and automotive transportation. The electric car, cited by the author as a possibility in the earlier volume, is rapidly becoming a reality, as a result. The brownouts and blackouts of the late sixties are a direct consequence of man's insatiable need for electric power, generally; and extended reliance on electric machinery, specifically. And the seventies inevitably will see an intensified interest in electrical energy conversion and machinery, on the part of governments, educational institutions, and industry, in response to these pressing global problems.

A strong attempt has been made to unify the subject matter and its method of presentation, as begun in the earlier work. Chapter 1 conveys the unifying principle that generator and motor action simultaneously occur in all rotating machines. Chapter 2 treats windings on the basis of similarities rather than differences between dc and ac dynamos. Chapters 5 and 7 treat armature reaction and parallel operation, respectively, in a similar unified way, leading to generalizations regarding the effects of excitation and armature reaction on all dynamos. Chapters 8 and 9 stress the distinctions between synchronous and asynchronous dynamos, always directed to the increased understanding of the characteristics of alternators, synchronous motors, induction motors and generators, and various single-phase motors. Chapter 11 on specialized dynamos includes selsyns, servomotors, and multifield exciters as well as other cross-field machines, essential for a study of servomechanisms. Dynamo efficiency is treated in Chapter 12 as a unified topic in electromechanical conversion, in which dc and ac dynamo efficiency and the underlying theory of basic tests are closely related. This chapter also gives particular attention to the rating, selection, speed control, and maintenance of electric machinery. The final chapter on transformers is closely related and referred to previous chapters on alternators and efficiency to stress similarities and unify the presentation. This chapter also includes higher order polyphase conversions for high power dc requirements.

As noted earlier, the emphasis of the writing, based on the author's quarter century of teaching experience, is directed toward self study. This has resulted in somewhat more detail in text material, illustrative examples indicating solution of problems, and many specific questions designed to motivate reading. It also has the advantages of decreasing the teacher's work load and placing more responsibility on the student in the learning process. Consequently, this frees the teacher to place more stress on those aspects of the subject he feels requires emphasis or in-depth study, and on those particular topics which students require help. Further, because of its self-study aspect, the work lends itself to either a two-semester or one-semester course on the subject. In the latter case, the teacher may assign specific chapters and/or sections of chapters as representing the course outline, with the preliminary injunction to the student to read whatever peripheral explanatory material he may require in other chapter sections, to broaden and enhance his understanding.

Thanks and appreciation is expressed to the Prentice-Hall staff, generally, and particularly to Steven Bobker for his careful supervision of the production of the manuscript and the many helpful suggestions which resulted in the present format of the book. The author also acknowledges the support and help of Mr. Matthew Fox, Executive Editor and Mr. Edward Francis, Editor, Electronic Technology.

As in the case of my other books and editorial work, my wife, Ruth, has made significant contributions directly in the proofreading and indexing of this entire ms and indirectly by her encouragement, patience and understanding through the many days of loneliness and isolation required to produce this work.

IRVING L. KOSOW

New York City, 1971

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electromechanical fundamentals

For a number of years the fields of electric power generation and conversion have occupied a subordinate place in the public mind in comparison to the more glamorous fields of electron-tube and solid-state electronics. Electrical engineers, scientists, professors, and their students have considered electric power a rather sterile field of study, generally lacking opportunity, challenge, or excitement. Yet a number of studies, national and international, which have estimated our fossil fuel reserves (coal, gas, and petroleum accounting for 96 per cent of our energy supply), our population growth, and our rising standard of living, predict an optimistic estimated fuel reserve of about 230 years and a pessimistic estimated reserve of 23 years*. New sources of energy as well as improved methods of energy conversion are indicated. Man's insatiable explorations into the ocean depths and outer space have begun to stimulate investigation of other means of energy conversion (solar, biochemical, chemical, and

* J. A. Hutcheson, "Engineering for the Future," *Journal of Engineering Education* (April 1960), pp. 602–607.