THE INDUCTION MOTOR. A SHORT TREATISE ON ITS THEORY AND DESIGN, WITH NUMEROUS EXPERIMENTAL DATA AND DIAGRAMS

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The Induction Motor.

A Short Treatise on its Theory and Design, with Numerous Experimental Data and Diagrams.

BY

B. A. BEHREND,

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"The absence of analytical difficulties allows attention to be more easily concentrated on the physical aspects of the question, and thus gives the student a more vivid idea and a more manageable grasp of the subject than he would be likely to attain if he merely regarded electrical phenomena through a cloud of analytical symbols."

J. J. THOMSON.

NEW YORK

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TO

MY FRIEND AND TEACHER

MR. GISBERT KAPP

I INSCRIBE THIS WORK.

PREFACE.

The literature of electrical engineering has become so vast and extensive that it is impossible for any man to keep pace with all that is written on electrical subjects. He who produces a new book that adds to the swelling tide of new publications, may justly be asked for his credentials. My justification for writing this tract will be found in the fact that, though almost all branches of applied electricity have enlisted the industry of authors, the induction motor has received comparatively little attention from competent engineers. The few whose experience and knowledge would entitle them to speak with authority on this subject are deterred from publishing by commercial reasons.

I have made the induction motor the subject of early and special studies, and a comparison of my treatment of its theory with the purely analytical theories will show how far I have succeeded in simplifying and elucidating so complex a subject. The graphical treatment of abstruse natural phenomena is constantly gaining ground, and I quote with satisfaction the words of so great a mathematician as Prof. George Howard Darwin, Fellow of Trinity College, Cambridge, who says on p. 509 of the second volume of Lord Kelvin and Prof. Tait's Treatise on Natural Philosophy that "the simplicity with which complicated mechanical interactions may be thus traced out geometrically to their results appears truly remarkable."

All through this little book I have endeavored to let inductive method check at every step the mathematical or graphical deduction of the results. A wide experience with mono- and polyphase alternating current induction motors, gained at the Oerlikon Engineering Works, Switzerland, has enabled me to do so. Thus the careful reader who is willing to profit by the experience of others, will find many valuable hints and results which he can turn to account in his

practice. Many induction motors have been designed on the principles laid down in this little treatise, and in no case has the theory failed to answer the questions suggested by observation.

The writing of this book has been mainly a labor of love. Those who know of the troubles, cares and labor involved in writing a book and bringing it through the press, not to mention the sacrifice of personal experience by publication, will doubtless be able to appreciate this thoroughly.

I wish to thank the editors of the ELECTRICAL WORLD AND ENGINEER for the pains they have taken with the publication of this book, and I must specially thank Mr. W. D. Weaver for the encouragement he has always given to me. To Mr. T. R. Taltavall, Associate Editor of ELECTRICAL WORLD AND ENGINEER, who has taken endless pains with the proofs of this book, I feel very much indebted.

The substance of this volume was delivered in January, 1900 in the form of lectures at the University of Wisconsin, Madison, Wis., and I wish to thank Prof. John Butler Johnson, Dean of the College of Mechanics and Engineering, for the invitation as non-resident lecturer which he extended to me. To him and to Prof. D. C. Jackson I am greatly indebted for the hospitality conferred upon the stranger within their gates.

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THE INDUCTION MOTOR

CHAPTER I.

The General Alternating Current Transformer.

1. The problem of problems, in the solution of which the electrical engineer is deeply interested, and which underlies all others, is set before us in the form of the alternating current transformer possessing considerable leakage and a relatively large magnetizing current.

2. A transformer with an open secondary takes from the primary mains just so much current as is necessary to produce a magnetic field which can balance the primary voltage. This current—neglecting for the moment hysteresis and eddy currents—lags behind the primary voltage by a quarter of a phase; hence the work done by this current is zero, and the magnetizing current is therefore a "wattless" current. This consideration is true only for a transformer without leakage. The magnetizing current need not be a wattless current in the sense in which this term is generally used. We shall learn more about this in Chapter VIII.

3. If you throw a non-inductive load upon the secondary, that is to say, if the secondary of the transformer be closed through a resistance, then the impedance represented by the action and reaction of the primary and the secondary system of the transformer, is diminished, permitting a larger current to flow. If, for didactic purposes, we make the assumption that the whole magnetic flux of the primary is transmitted without loss into the secondary, and vice versa, then the vector of the primary current must be composed of two vectors, the one representing the magnetizing or wattless current, lagging behind the terminal volts by a quarter of a phase, and the other representing the watt current and being in phase with the ter-