

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

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649462889

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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**B. A. BEHREND**

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# The Induction Motor.

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

BY

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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.

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NEW YORK  
ELECTRICAL WORLD AND ENGINEER  
INCORPORATED

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JUN 4 1901

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TO

MY FRIEND AND TEACHER

MR. GISBERT KAPP

I INSCRIBE THIS WORK.

## PREFACE.

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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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1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in the context of public administration and financial management. The text notes that without reliable records, it is difficult to track expenditures, assess performance, and ensure that resources are used efficiently and effectively.

2. The second part of the document addresses the challenges associated with data collection and analysis. It highlights that gathering accurate and timely data can be a complex task, often requiring significant resources and expertise. The text discusses various methods for data collection, including surveys, interviews, and the use of digital tools, and notes that each method has its own strengths and limitations. Additionally, it points out that data analysis is a critical step in understanding the underlying trends and patterns in the data, and that this process often involves the use of statistical techniques and software tools.

3. The third part of the document focuses on the importance of data security and privacy. It stresses that as the volume and sensitivity of data increase, the risk of data breaches and unauthorized access also increases. The text discusses various security measures, such as encryption, access controls, and regular security audits, and notes that these measures are essential for protecting sensitive information and maintaining the trust of stakeholders. It also mentions that data privacy regulations, such as the General Data Protection Regulation (GDPR), have become increasingly stringent, and that organizations must ensure they are compliant with these regulations to avoid legal consequences.

4. The fourth part of the document discusses the role of data in decision-making and strategic planning. It notes that data-driven insights can provide valuable information for identifying opportunities, assessing risks, and making informed decisions. The text emphasizes that data should not be used in isolation, but rather in conjunction with other factors, such as expert judgment and stakeholder input, to ensure that decisions are well-rounded and effective. It also mentions that data can be used to monitor and evaluate the performance of various initiatives, allowing organizations to make adjustments as needed to improve their outcomes.

5. The fifth and final part of the document discusses the future of data and the role of emerging technologies. It notes that advances in artificial intelligence, machine learning, and big data analytics are transforming the way data is collected, analyzed, and used. The text discusses the potential benefits of these technologies, such as improved accuracy and efficiency in data processing, and also notes the challenges they pose, such as the need for specialized skills and the risk of bias or discrimination. It concludes by emphasizing that organizations must stay up-to-date on the latest developments in data technology to remain competitive and effective in the future.

# 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-