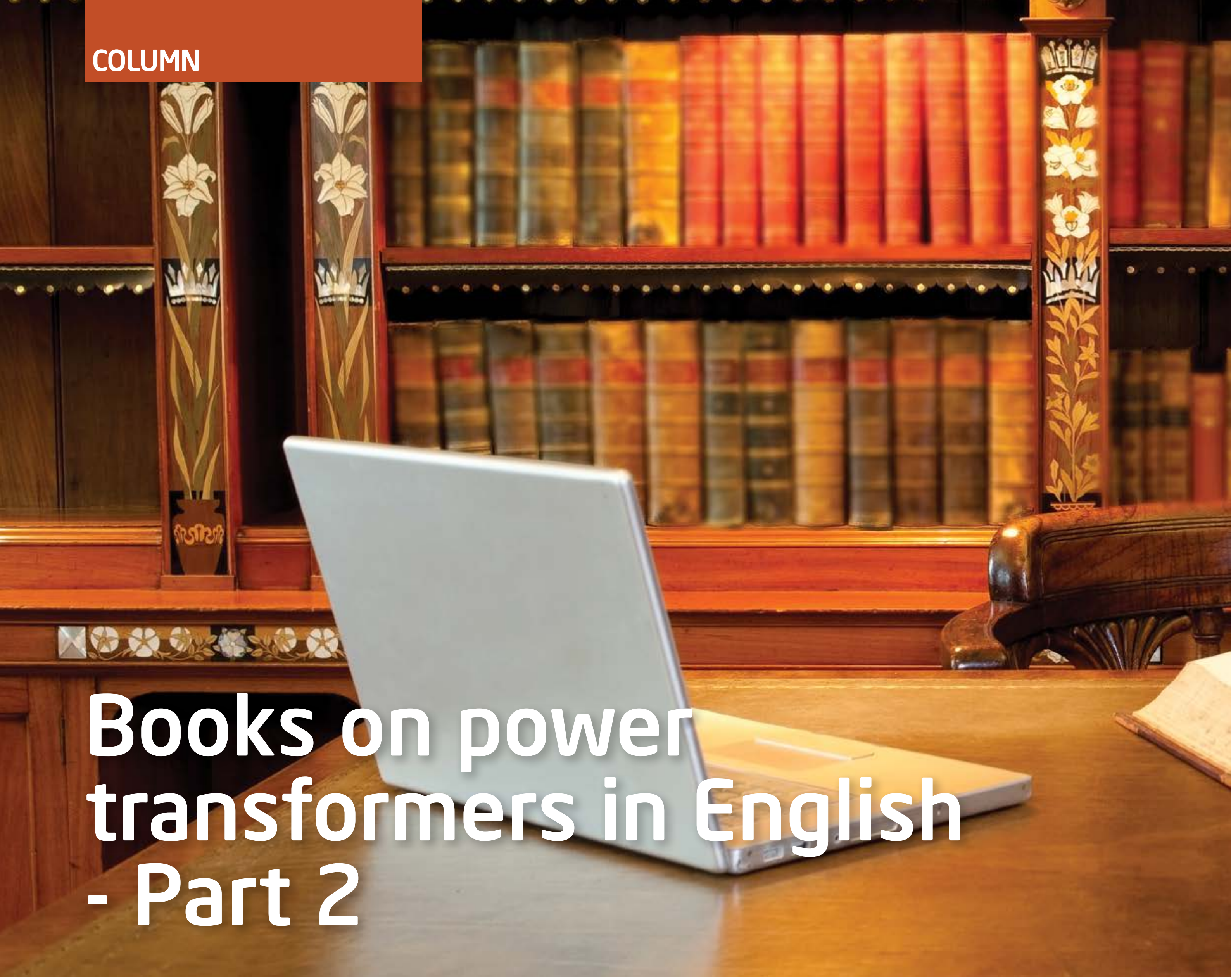


COLUMN

Books on power transformers in English - Part 2

ABSTRACT

In this second part of the column about the books on power transformers, we explore two books from the early 1900s. Those are The Alternating Current Transformer by Frank George Baum, published in 1903, and Transformer Practice, Manufacture, Assembling, Connections, Operation and Testing by William T. Taylor, published in 1909. These exciting books are a testament to the historical development of transformer technology.

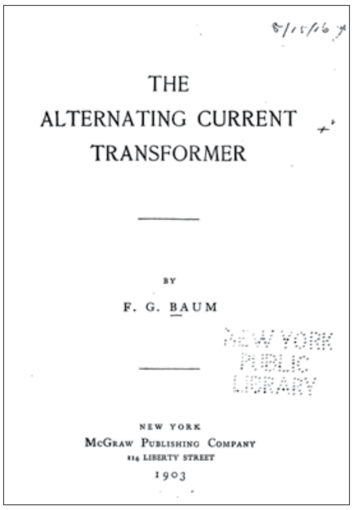
KEYWORDS

books, literature, early 1900s, efficiency, testing, manufacturing, insulation, technology

1903

Frank George Baum (1870-1932), The Alternating Current Transformer, McGraw-Hill Publishing Company, New York, 195 pages, 1903, available at https://books.google.com.ua/books/about/The_Alternating_Current_Transformer.html?id=ifBOAAAAMAAJ&redir_esc=y

The book is based on the lectures from Prof Baum at Stanford University, USA, for a course on transformers. Chapters 1 and 2 are introductory chapters covering elementary principles and transformer vector diagrams. Transformer parameters like magnetic induction, magnetomotive force, the strength of the magnetic field, and induced emf are explained with the connecting formulae derived. Chapter 3 covers a graphical representation of pressure relations (the term used those days for voltage) for transformers, i.e., a vector diagram. Chapter 4 derives the formula for voltage regulation with secondary loading. Chapter 5 discusses the efficiency of full load and part loads. Since the core losses of 5 number 1 kV transformers were 3.5x5=17.5% against 2.25% for a 5 kV rating, utilities preferred larger rated units due to the lower % of losses in the transformer.


THE
ALTERNATING CURRENT
TRANSFORMER

BY
F. G. BAUM

NEW YORK
McGRAW PUBLISHING COMPANY
114 LIBERTY STREET
1903

In 1890, a 1/2 kW transformer had a 10 % core loss, which dropped to half by 1900. Percentage impedance was 3-6%. Total losses of small transformers rated 1/2 -20 kW were 6-3 %. This heat was dissipated by natural air cooling, forced air cooling, or water cooling. Temperature rise over the surrounding air was kept below 50°C to reduce the ageing of insulation and iron core sheets.

Large transformers were assembled in cast iron boxes with oil filling. The active part was dried to remove moisture by applying voltage to one winding. Large, rated units were oil-filled under a partial vacuum to remove air.

Transformer Rating kW	Core Loss % of Rating	Copper Loss % of Rating	No-load Current % (max)
1	3.5	3	7
5	1.5	2.25	3
10	1.4	2	2.8
50	-	1.5	-

The book describes tests such as the ratio & polarity, regulation (voltage drop at rated load), core loss and exciting current, copper loss, insulation withstand, and temperature rise at full load

Chapter 6 covers the testing of transformers. Tests conducted at the factory were ratio & polarity, regulation (voltage drop at rated load), core loss and exciting current, copper loss, insulation withstand, and temperature rise at full load. The AC test voltage for two kV-rated transformers was 10 kV AC between HV-earth and

HV-LV insulations and 2.5 kV between LV-core. The insurance companies insisted on these test voltages for the insulation, almost ten times the working voltage!

The systematic design of core and shell-type transformers, used in the first decade of the 20th century, is explained in Chapter 7. The design procedure was almost the same or similar to the one formulated by Mr. Gisbert Kapp in his books, published earlier. A section of the chapter describes a method to determine the specific losses (W/kg of hysteresis and eddy losses) of the annealed iron sheets (14 mils 0.35 mm thick) used in the manufacture of cores for transformers. Some typical design calculations for shell and core-type transformers are given. The design of induction coils (shunt reactors) used in HV lines (60 kV Class transmission line, 150 miles long at 60 c/s) is briefly mentioned. These reactors neutralised 50% of the charging current in long HV lines. Compensators or economy coils (also called auto-transformers) were built those days, but mentioned, "as a transformer, this method of construction is very inferior in every way to two winding transformers." These were mainly used for starting large induction motors.

Some types of special transformers of those days are described in Chapter 8. Circuit regulators (boosters as of now) of different designs were used – Stillwell regulator by Westinghouse and GE – to independently control the sending end voltage of individual parallel lines connected to a single generator. Constant current transformers, series transformers (current transformers), and compensating voltmeters are also covered.

Chapter 9 explains the popular transformer connections used at the beginning of the last century. Series-parallel connection of windings in single phase transformer was standard to get multi-voltage ratios. In three-phase connections, the Delta-delta connection was for converter transformers. The delta-star connection was standard, "to balance the loads, one side of the transformer is usually connected in delta, wherever possible" (page 137). In an AIEE paper of November 22, 1901, W.L.R. Emnet advocated a three-phase system in place of single-phase or two-phase for AC distribution due to the superior aspects of three-phase significantly less copper requirement for transmitting a specific amount of power. Various connections employed for converting two-phase to three-phase power are mentioned, emphasising the superiority of the connection developed by C.F. Scott for the Niagara Project.

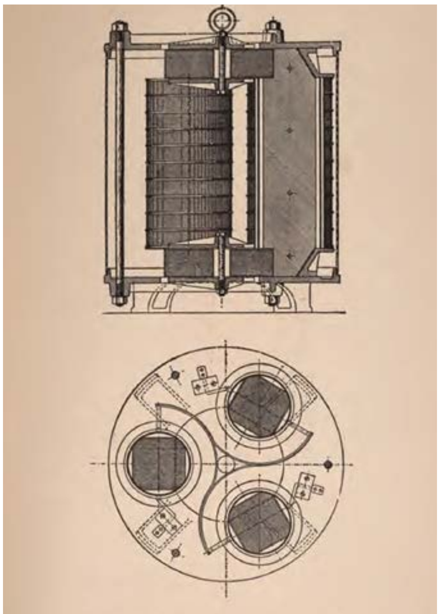
Chapter 10 lists the salient features – design and constructional details with photographs, of transformers manufactured in 1900 by the leading electrical companies in the US and Europe

Chapter 10 lists the salient features (design, constructional details with photographs) of transformers manufactured in 1900 by the leading electrical companies in the US and Europe.

1. The Converse Transformer Company, Pittsburg, Pa, USA – 333 kW 80 kV water cooled three phase transformer
2. General Electric, USA – 800 kW shell type, water-cooled transformer
3. Moloney Electric Co, St. Louis. Mo, USA
4. New York & Ohio Co, Warren, Ohio-Packard Transformers
5. Stanley Electric Company, Pittsfield, Mass, USA – Ao Transformers
6. Westinghouse Electric & Mfg Co Pittsburg, Pa
7. Allgemeine Elektricitäts Gesellschaft, Germany
8. Brown Boveri Co, Switzerland
9. Maschinenfabrik Oerlikon, Switzerland


300 kW three-phase transformer

10. Ferranti Transformers, UK
11. Ganz Co, Hungary
12. Elektrizitäts Aktiengesellschaft, Germany


Three-phase transformer

13. Brush Electrical Engineering Co, UK

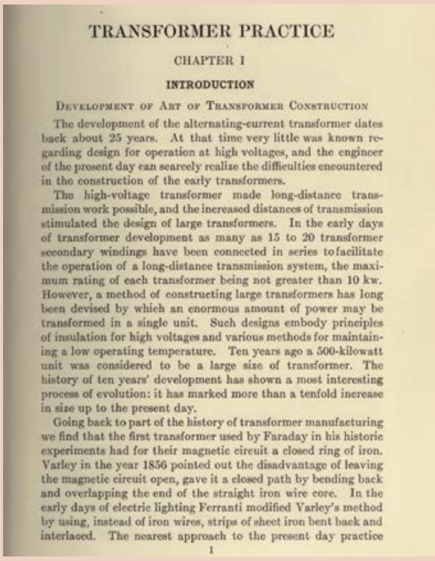
An Appendix extracts the rules and requirements of the National Board of Fire Underwriters covering the construction and test requirements, installation, location, and grounding of low potential (LV) circuits.

1909

William T Taylor was a consulting engineer for hydroelectric power projects and high-voltage power transmission who installed hydroelectric projects in India (Kashmir), Mexico, and South America (Peru)

William T Taylor, *Transformer Practice, Manufacture, Assembling, Connections, Operation and Testing,* McGraw-Hill Publishing Book Company Inc, New York, 1st edition, 191 pages 1909, 2nd edition, 292 pages, 1913, available at https://ia904704.us.archive.org/16/items/transformerpract00tayluoft/transformerpract00tayluoft.pdf

In his book, William T Taylor shows a figure indicating the growth in the unit rating of transformers and the voltage class of transformers until 1913



TRANSFORMER PRACTICE

CHAPTER I

INTRODUCTION

DEVELOPMENT OF ART OF TRANSFORMER CONSTRUCTION

The development of the alternating-current transformer dates back about 25 years. At that time very little was known regarding design for operation at high voltages, and the engineer of the present day can scarcely realize the difficulties encountered in the construction of the early transformers.

The high-voltage transformer made long-distance transmission work possible, and the increased distances of transmission stimulated the design of large transformers. In the early days of transformer development as many as 15 to 20 transformer secondary windings have been connected in series tofacilitate the operation of a long-distance transmission system, the maximum rating of each transformer being not greater than 10 kw. However, a method of constructing large transformers has long been devised by which an enormous amount of power may be transformed in a single unit. Such designs embody principles of insulation for high voltages and various methods for maintaining a low operating temperature. Ten years ago a 500-kilowatt unit was considered to be a large size of transformer. The history of ten years' development has shown a most interesting process of evolution: it has marked more than a tenfold increase in size up to the present day.

Going back to part of the history of transformer manufacturing we find that the first transformer used by Faraday in his historic experiments had for their magnetic circuit a closed ring of iron. Varley in the year 1856 pointed out the disadvantage of leaving the magnetic circuit open, gave it a closed path by bending back and overlapping the end of the straight iron wire core. In the early days of electric lighting Ferranti modified Varley's method by using, instead of iron wires, strips of sheet iron bent back and interlaced. The nearest approach to the present day practice

1

William Thomas Taylor (1877-1945) was from England (Burnley), moved to South Africa and later to GE, US, and was a Fellow of the Institute of Electrical Engineers. He was a consulting engineer for hydroelectric power projects and high-voltage power transmission. He has installed hydroelectric projects in India (Kashmir), Mexico, and South America (Peru). When he was writing the preface to the first edition of this book, he was in Baramulla, Kashmir, India (December 1908), and the preface to the second edition was written at Chaplanca, Peru (August 1913) as he was executing projects in those countries. Details below are from the book's second edition, published in 1913.

Please find the Introductory chapter of the book. The author also shows a figure indicating the growth in the unit rating of transformers and the voltage class of transformers until 1913. The maximum size of the transformer was 15 MVA 145 kV, and we saw similar sketches in later transformer books, articles, and brochures from manufacturers.

Apart from the fundamentals, the book had chapters for special transformers such as auto-transformers, constant current transformers, series transformers, regulators, and six-phase transformers. The title also covered transformer connections, manufacturing aspects, cooling alternatives, operation, and testing details. Specifications of several typical ratings are also given in the last chapter. A 1000 kW 60 kV 25 cycles, single phase shell type unit had 97.8% efficiency with iron and copper losses of 7.3 and 9.6 kW with exciting current of 14 A and impedance volts of 1.7 volts. It had 1300 gallons of oil. The size of LBH was 110x59x135 inches 30,000 +10,400 lbs.

A 200 kW 57.5 kV 25 cycles, core type, single phase unit had 96.7% efficiency with losses of 2.9 +1.75 kW and impedance volts of 1.02 V from the HV side and excitation current of 10.3 A. The size of LBH was 64x47x103 inches. It had 150 gallons of oil and a total weight of 10,000 +3000 lbs.

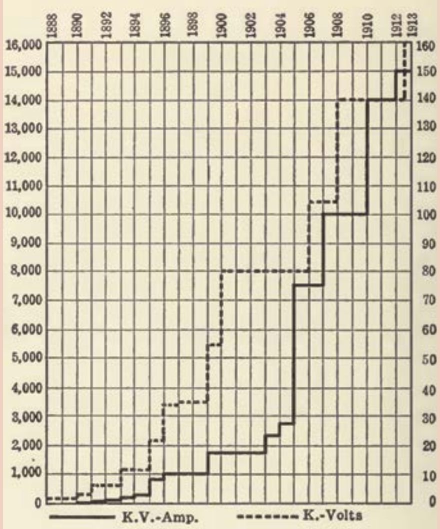


FIG. 1.—Transformer development.

Authors

P. Ramachandran started his career in transformer industry in 1966 at TELK, Kerala, a Hitachi Joint venture, in India. He worked with ABB India during 1999-2020. He has more than 50 years of experience in the design and engineering of power products including power transformers, bushings, and tap-changers. He received Bachelor of Science Degree in Electrical Engineering from the University of Kerala, India, and Master of Business Administration Degree from Cochin University, India. He is a Fellow of Institution of Engineers (India), and he represented India in CIGRE Study Committee A2 for transformers during 2002 – 2010.

Vitaly Gurin graduated from Kharkov Polytechnic Institute (1962) and graduate school at the Leningrad Polytechnic Institute. Candidate of technical sciences in the Soviet scientific system (1970). For 30 years he tested transformers up to 1.150 kV at ZTZ, including the largest one of that time in Europe, and statistically analysed the test results. For over 25 years he was the Executive Director of Trafoservis Joint-Stock Company in Sofia (the diagnosis, repair and modernisation in the operating conditions of transformers 20 – 750 kV). He has authored about 150 publications in Russian and Bulgarian, and is the main co-author of GOST 21023.