

Preface

The main task of **high voltage engineering** is to gain *technological control of high electrical field strengths and voltages*. Their effects can impressively be observed in nature (or in a high voltage laboratory) as “lightning and thunder phenomena” if the “insulation system consisting of air” is failing. Formerly, historical authorities such as Zeus, Jupiter or Wotan have been responsible for these natural forces and their risks. But now, the high voltage engineers guarantee for the safe and reliable function of all electrical insulation systems. Only in this way, all the other technical applications of electricity are made available. In consequence, high voltage technology is both a *key technology* for a wide spectrum of technical applications that are indispensable for the modern society and a *cross-sectional technology* integrating different scientific disciplines. High voltage engineering is a fascinating, challenging, interdisciplinary and multifaceted field of activity that will always be a prerequisite and essential support for the technical progress.

High voltages enable the *generation, transmission and distribution* of electrical energy at relatively low currents and ohmic losses. The minimization of power loss preserves resources and reduces emissions and it is therefore a prerequisite for secure, economical and eco-friendly electricity supply. Furthermore, high voltage and ultra-high voltage AC and DC networks are prerequisites for the development of remote energy sources, for the large-area load balancing and for a transnational energy market. Additionally, high voltage technology has wide-ranging *industrial applications*, such as for example X-ray devices, lasers, high efficiency light sources, lithotripters, shock wave generators, fragmentation devices, accelerators, transmitter tubes, copiers, electrostatic precipitator or coating and enameling devices. Problems of high voltage engineering must also be tackled in power electronics and for the electromobility, in the area of electromagnetic compatibility, in physical and technological research, or in the field of high-temperature superconductivity. For all applications it is common to choose **high electrical field strengths** on the one hand in order to ensure that the dimensions, weight, material usage, costs, losses and environmental pollution remain as low as possible. On the other hand,

the **electric field stress** must *always* be *lower* than
the **dielectric strength** of the insulating materials

so that discharges and a destructive breakdown can definitely be excluded. Between these poles, the tasks of engineers are largely to implement economical and technically optimal system solutions. For that purpose, high voltage engineers should be primarily wide ranging and practice oriented and should have a theoretically sound overview.

The **concept of the book** consists of a systematic, coherent and comprehensive presentation of
fundamentals, technologies and applications.

For this purpose, high voltage engineering is classified into six main topics:

- **Electrical stresses** by fields and waves (Chapter 2)
- **Dielectric strength** of gases, liquids and solids (Chapter 3)
- **Dielectric system characteristics** of insulating materials (Chapter 4)
- **Insulating materials** and their technology (Chapter 5)
- **Testing, measurement and diagnosis** (Chapter 6)
- **Typical insulation systems** for different types of stresses (Chapter 7).

Already the basic Chapters 2, 3 and 4 include practical examples, applications, notes and exercises. Also the description of technologies and applications in the Chapters 5, 6 and 7 is always related to the fundamentals. Special emphasis is laid on the presentation of scientific and practical contexts as well as on *clarity in words and illustrations*. A comprehensive *keyword index* and an extensive *bibliography* shall facilitate access to special issues and to further sources for the reader.

The book is therefore suitable both for the initial training of high voltage engineering in class-room studies or private studies and for the deeper guidance to specific areas and to specialist technical literature. It is intended to be useful as a *workbook in academia and in the professional work*.

This edition of “High Voltage Engineering” is equivalent to the fourth edition of the German reference book “Hochspannungstechnik”, and for the first time it is also published in English language. For more than 20 years, the **previous German editions** are widely used by undergraduate and post-graduate students, engineers, scientists, universities, manufacturers, service companies and utilities. In 1996 the first edition was initially developed from the author’s lectures at the University of Applied Sciences Würzburg-Schweinfurt. The new editions in 2004, 2009 and 2017 were always stimulated by strong interests of the readership. In each case, comprehensive revisions, adaptations to the state of the art, stronger involvements of application subjects and inclusions of new and innovative topics were made.

Therefore, the **English edition** includes numerous improvements in details and many extensions and new features being related to the great *actual challenges* in high voltage engineering. For example, ultra-high voltage AC and DC transmission with voltages of more than 1,000 kV, DC cable runs with more than 500 kV, switchgear with alternative insulating gases and transformers with alternative insulating liquids are built. That’s why the sections about insulation systems for *high voltage DC transmission* in Chapter 7 were fundamentally revised and much expanded, regarding stresses, dielectric strength and design for DC voltages and with regard to transformers, bushings, cables and fittings for HVDC. This is supplemented in Chapter 3 and 6 by sections about the generation and evaluation of *partial discharges* at DC voltage. Additional current topics are the introduction of so-called “*alternative*” *climate-friendly insulating gases* instead of SF₆ and the use of so-called “*alternative*” *eco-friendly insulating liquids* instead of mineral oil. Revisions have also been made in the sections about the *conduction behavior* and the *dielectric behavior* of solid and liquid dielectrics (Chapter 4), about the *oscillating behavior* during impulse voltage tests (Chapter 6) and about *transformer testing* (Chapter 7). On the suggestion of renowned expert colleagues, it is finally proposed in Chapter 3 that the term “*electronegativity*”, which is commonly used in high voltage engineering, should be replaced by the term “*electron affinity*”.

At various places in the text, references to new *technical regulations* and *standards* are also made. This is, however, possible only in extracts or examples, according to the current but impermanent status of standardization. The reader must finally consult the appropriate valid and updated regulations and standards directly. The limited space of the book naturally necessitates also intense abridgement of many contents and a very subjective compromise between *completeness* and *depth*. I therefore request all experts to be lenient towards the author if they find their special subject to be inadequately dealt with. I hand over this book to the reader, with a request for comments and suggestions which are always welcome. Please contact Andreas.Kuechler@fhws.de.

Now, my personal recommendation would be “*to read with a pen*”, that is, to understand the examples, exercises and field plots through own calculations and to delve into interesting topics through

written side notes and extracts. Useful supplements for this could be a mathematical formulary and textbooks on experimental physics, basic electromagnetic theory or material sciences.

Many **expert colleagues and friends** have supported me during the creation of the first three German editions. As I could already express my gratitude for their help in these preceding editions, I now want to thank all direct and indirect supporters who were the prerequisite for the fourth German edition and for the first English edition of “High Voltage Engineering” in the present form.

With many colleagues from universities I could conduct an intensive scientific discourse, for which I would like to give my thanks to the professors Dr. *R. Bärsch*, Dr. *F. Berger*, Dr. *G. Chen*, Dr. *Ch. Frank*, Dr. *S. Grossmann*, Dr. *S. Gubanski*, Dr. *V. Hinrichsen*, Dr. *F. Jenau*, Dr. *M. Koch*, Dr. *J. Kindersberger*, Dr. *M. Liebschner*, Dr. *H. Okubo*, Dr. *R. Patsch*, Dr. *R. Plath*, Dr. *K. Rethmeier*, Dr. *M. Rossner*, Dr. *S. Tenbohlen*, Dr. *W. S. Zaengl* (†) and Dr. *M.H. Zink*.

Furthermore, my sincere thanks go to Dr. *I. Atanasova-Höhlein*, Dr. *K. Backhaus*, *S. Bhumiwat*, *M. Chmielewski*, Dr. *W. Exner*, *S. Eyring*, Dr. *J. Fabian*, Dr. *R. Färber*, *R. Fritsche*, Dr. *J. Fuhr*, Dr. *W. Hauschild*, *A. Hopf*, *M. Hörmann*, Dr. *Ch. Hurm*, Dr. *S. Jaufer*, Dr. *U. Kaltenborn*, *Ch. Krause*, Dr. *M. Krüger*, *N. Kurda*, *A. Langens*, Dr. *C. Leu*, *L. Lundgaard*, *M. Pegelau*, Dr. *R. Pietsch*, Dr. *U. Piovan*, *B. Preidecker*, Dr. *U. Prucker*, *K. Rädlinger*, *M. Rösner*, *J. Roßmann*, Dr. *J. Schiessling*, *B. Schlittler*, *Ph. Schmitt*, *T. Schnitzer*, *J. Seiler*, *B. Spatta*, Dr. *J. Speck*, *Th. Steiner*, *J. Titze* and *E. Zerr* for many expert discussions and suggestions. I am also grateful to the companies that contributed to the preparation of the editions by photographic material and professional exchange.

The University of Applied Sciences Würzburg-Schweinfurt (FHWS) and the Faculty of Electrical Engineering provided a sound scientific basis for this publication by the implementation of high voltage engineering in teaching and research. And of course, my students have been a great help owing to their questions, contributions and theses. Important scientific and professional support was also given by our current and former staff members *M. Fell*, *S. Harrer*, *B. Hochbrückner*, *F. Hüllmandel*, *F. Klauer*, *H.-P. Öftering*, *A. Reumann*, Dr. *F. Schober*, *S. Sturm*, *F. Swobodnik* and *I. Wirth*. I am also very grateful for that.

Furthermore, *Omicron Electronics GmbH* and *B. Walker* deserve very high recognition and reward for the great assistance in translating from German to English.

Finally, special thanks go to Ms. *S. Bromby*, to Mr. *Th. Lehnert* and to *Springer-Verlag GmbH* for editing the book, for great patience and understanding and for very good cooperation.

Last but not least, these thanks also include my family. My sons *Florian* and *Sebastian* could provide valuable tips from the students’ perspective. Also my parents *Ursula* and *Johannes* contributed significantly to the development of the work because of their continuous encouragement and permanent support. Nevertheless, the realization of the edition was primarily achieved due to the great understanding, the strong backing and the enormous patience of my wife *Christiane*.

Schweinfurt and Hammelburg, March 2017

Andreas Küchler

High Voltage Engineering
Fundamentals - Technology - Applications
Küchler, A.
2018, XXIII, 650 p. 441 illus., Hardcover
ISBN: 978-3-642-11992-7