High Voltage Engineering in Power Systems

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PREFACE

This book is the first to address in a totally unique scope the field of high voltage engineering, presenting the core of the subject matter, applications, and effects.

Subject matter presentation commences with the two major sources of high voltage surges, namely switching (accidental and intentional) and atmospheric breakdown (lightning). Next the process of field-intensified ionization will be presented and then the phenomena of inducing and induced voltages will be treated analytically in terms of partial differential equations modeling and the application of the method of magnetic moments. Comprehensive analyses for the adverse effects due to the propagation of voltage and power surges on transmission lines, transformer, and insulating systems have been presented including interaction with conducting fluids, charged clouds, corona and skin effects, as well as the concept of energy storage and extraction from lightning and the negative effects of electromagnetics on health and environments. A special chapter has been devoted to the field of protection from high voltage surges.

This book supplements the comprehensive coverage of high voltage engineering with solved examples followed by a set of problems. It blends the areas of physics, engineering analysis and applications of high voltage engineering into a unified package suitable to the reader seeking physical and engineering understanding of this field.

To
Badia, Karem, Zayd and Athra

THE AUTHOR

Khalil Denno, Ph.D., is Distinguished Professor of Electrical Engineering at Newark College of Engineering, New Jersey Institute of Technology in Newark, N.J.

Dr. Denno received his M.E.E. degree in 1959 from Rensselaer Polytechnic Institute of Troy, N.Y. and his Ph.D. degree in 1967 from Iowa State University in Ames, Iowa. He joined Newark College of Engineering of New Jersey Institute of Technology as Associate Professor in 1969, was promoted to the rank of Professor in 1973, and then became Distinguished Professor in September 1987.

Dr. Denno is a Fellow of the Institution of Electrical Engineers (IEE), a senior member of the Institute of Electrical and Electronics Engineers (IEEE), and a member of the American Nuclear Society, the American Society of Engineering Education, and Sigma Xi Society. He had the honor of winning the 1982 Harlan Perlis Award for Excellence in Research, and has numerous listings in national and international honor societies and biographies.

Dr. Denno specializes in the fields of energy conversion, renewable energy sources, conventional power system, high voltage engineering, and magnetohydrodynamics. He is a Licensed Professional Engineer in New Jersey and Chartered Engineer in the United Kingdom. He is the author of *Power System Design and Applications for Alternative Energy Sources* (Prentice Hall, Inc.) and *Engineering Economics of Alternative Energy Sources* (CRC Press). Dr. Denno has published 120 research papers in leading national and international journals covering the fields of magnetohydrodynamic power generation, fusion energy, lightning phenomenon, particle accelerators, conventional energy systems, characterization of cold plasma and various modes of renewable energy sources.

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The author would like to thank the following publications for release of data and diagrams for use and publication in this book.

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TABLE OF CONTENTS

Chapter 1

SOURCES OF SURGE VOLTAGES

1.I INTRODUCTION

Main sources of high voltage surges are generally confined to intentional and unintentional switching operations in power systems as well as those induced by lightning phenomenon. Intentional switching may create certain sparks or discharges that may require a slow timing process to disappear due to effects caused by electrode heating and impurities accumulation across the spark gap. Unintentional switching could be caused by ground faults, sudden conductor breaks, accidental short-circuits, lightning strokes, and erroneous operation of switching devices. Current and voltage surges are usually of high amplitude and short in time duration, and of different span in frequency spectrum with a broad band in harmonies and as special distorted wave forms.

In this chapter, comprehensive presentation will be made regarding spark discharges due to switching, propagation at high voltage surges, propagation of discharge front with effects of power systems harmonizations, aspect of system oscillations, reignition, and modes of various spark arresters as well as the spectrum of natural frequencies associated with three phase systems under oscillations.

Discharges generated by lightning strokes which are much more powerful than those due to switching will be presented, including concepts of conductive and convective surges under conditions of varying pressure and temperature.

1.II PROPAGATION OF TRAVELING WAVES

Voltage or current surges initiated by switching or lightning will propagate at a velocity close to that of the velocity of light in overhead systems and at about half of that through underground installations. Numerous situations involving short distances of less than 50 miles, and instant computations for the build-up of voltage stresses on the basis of lossless representation of transmission lines could be secured with regard to short-circuit or open-circuit terminations as close equivalents for actual loading connections.