Preface

This book is based on notes for the Transformer Applications Course offered by the Center for Power System Study at Lehigh University. The key word in both the title of that course and the title of this book is *applications*. The material presented in the following chapters was obtained from various sources: textbooks, industry standards, and established utility practices and procedures. Much of this material also comes from my personal files relating to actual events and case studies that were observed during my career in the utility industry spanning 30 years.

There are many kinds of transformers, and all share the same set of fundamental operating principles. Since this book focuses on *power* transformers, it is fair to ask, ''What exactly *is* a power transformer?'' By definition, a power transformer is a transformer which transfers electric energy in any part of the circuit between the generator and the distribution primary circuits.* This definition of power transformer in the IEEE standard appears under the

* IEEE Std. C57.12.80-1978. IEEE Standard Terminology for Power and Distribution Transformers. Institute of Electrical and Electronics Engineers, Inc., 1978, New York, p. 8.

heading of ''Size'' and does not indicate how the transformer is used in the power system. Thus, this book uses this definition in the broadest sense to include discussions of specialty applications such as step voltage regulators, phase shifters, and grounding transformers, as well as the usual step-up and step-down applications. Since the line between power transformers and distribution transformers is somewhat blurry, many of the basic principles presented can be applied to distribution transformers as well.

The first several chapters build a solid theoretical foundation by describing the underlying physics behind transformer operation. A theoretical foundation is absolutely necessary in order to understand what is going on inside a transformer and why. The magnetic properties of materials, a review of magnetic units, and analysis of magnetic circuits are discussed with enough mathematical rigor for the interested reader to gain full comprehension of the physics involved. Whenever a detailed mathematical treatment is presented, it is always done with a practical objective in mind. Each chapter includes a number of practice problems to clearly illustrate how the theory is applied in everyday situations. Many of these practice problems are based on actual events.

Several things set this book apart from other transformer reference books. First, this book emphasizes the importance of magnetic properties and how the choice of a core design can affect the transformer's electrical properties, especially during faults and unbalanced operations. Many reference books overlook this critical aspect of transformer applications.

Next, this book discusses special types of transformer connections, such as the zigzag, Scott, and tee connections, as well as the more common wye and delta types. The Scott and tee connections, which transform three-phase voltages into two-phase voltages, are seldom covered in modern transformer reference books even though two-phase systems still exist today. Tap changing under load and variable phase shifting transformers are covered. Different types of transformer coil and coil construction are compared, with discussion of the particular advantages and disadvantages of each with respect to the various transformer connections. The reader will also gain insight into some of the economic trade-offs of different transformer design options.

A brief tutorial on symmetrical components is also included. The topic is covered in other reference books but seldom in such a compact and straightforward way, enabling the reader to immediately apply the technique in practical problems.

A section of the book defines a transformer's nameplate rating versus its thermal capability and describes how to calculate a transformer's rate of loss of life. An entire chapter is devoted to describing abnormal operating conditions that can damage power transformers, including overloads, short

circuits, single phasing from primary fuse operations, ferroresonance, and voltage surges. The chapter describes ways to avoid these conditions, or at least ways to mitigate them through proper system design and selection of appropriate transformer designs.

The reader will learn how to interpret and use a transformer test report as well as the information on the transformer nameplate. The book concludes with a comprehensive discussion of preventive and predictive maintenance, good utility practices, factory and field testing, and failure rate analysis.

This book is intended primarily for readers having an electrical engineering background although training as an electrical engineer is not necessary, and others will also benefit from the conclusions that can be drawn from the practical examples. Mastery of the principles presented in this book will provide a sound working knowledge of how to specify, operate, and maintain power transformers in a utility or plant environment.

I wish to thank Anthony F. Sleva for his thorough review of the manuscript and his many helpful suggestions for improving it, and for making it possible to publish this book. I am indebted to the late Charles H. Morrison, who patiently shared with me so much of his extensive theoretical and practical knowledge about power transformers.

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