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Design and Applications

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To my wife, Maggi, and to
Gigi, Mitzi and Natalie

The four pillars of my life

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PREFACE

Ever since the time when electrical energy was beginning to be utilized, there has been a need for suitable switching devices capable of initiating and interrupting the flow of the electric current. The early designs of such switching devices were relatively crude and the principles of their operation relied only on empirical knowledge. Circuit breakers were developed on the basis of a "cut and try" approach, but as the electrical system capacity continued to develop and grow, a more scientific approach was needed to achieve optimized designs of circuit breakers that would offer higher performance capabilities and greater reliability.

The transition of current interruption from being an empirical art to an applied science began in the 1920's. It was only then that worldwide research started to unravel the subtleties of the electric arc and its significance on the current interruption process. Since those early research days, there has been a great deal of literature on the subject of current interruption. There have also been numerous technical articles on specific applications of circuit breakers, but most of these publications are highly theoretical. What has been missing are publications geared specifically to the needs of the practicing engineer—a simple source of reference that provides simple answers to the most often asked questions: Where does this come from? What does it mean? What can I do with it? How can I use it? How can I specify the right kind of equipment?

Circuit breakers are truly unique devices. They are a purely mechanical apparatus connected to the electrical system. They must systematically interact with the system, providing a suitable path for the flow of the electric current; furthermore, they must provide protection and control of the electric circuit by either initiating or stopping the current flow. Combining these tasks into one device requires a close interaction of two engineering disciplines. A good understanding of mechanical and electrical engineering principles is paramount for the proper design and application of any circuit breaker.

The purpose of this book is to bridge the gap between theory and practice, and to do so without losing sight of the physics of the interruption phenomena. The approach is to describe the most common application and design requirements and their solutions based on experience and present established practices. A strictly mathematical approach is avoided; however, the fundamentals of the processes are detailed and explained from a qualitative point of view.

Beginning with a simplified qualitative, rather than quantitative, description of the electric arc and its behavior during the time when current is being interrupted, we will then proceed to describe the response of the electric system and the inevitable interaction of current and voltage during the critical initial microseconds following the interruption of the current. We will show the specific behavior of different types of circuit breakers under different conditions.

After explaining what a circuit breaker must do, we will proceed to describe the most significant design parameters of such device. Particular emphasis will be placed in describing the contacts, their limitations in terms of continuous current requirements and possible overload conditions, and their behavior as the result of the electromagnetic forces that are present during short circuit conditions and high inrush current periods. Typical operating mechanisms will be described and the terminology and requirements for these mechanisms will be presented.

Over the years performance standards have been developed not only in the United States but in other parts of the world. Today, with the world tending to become a single market, it is necessary to understand the basic differences among these standards. Such an understanding will benefit anyone who is involved in the evaluation of circuit breakers designed and tested according to these different standards.

The two most widely and commonly recognized standards documents today are issued by the American National Standards Institute (ANSI) and the International Electrotechnical Commission (IEC). The standards set fort by these two organizations will be examined and their differences will be explained. By realizing that the principles upon which they are based are mainly localized operating practices, it is hoped that the meaning of each of the required capabilities will be thoroughly understood. This understanding will give more flexibility to the application engineer for choosing the proper equipment for any specific application and to the design engineer for selecting the appropriate parameters upon which to base the design of a circuit breaker, which must meet the requirements of all of the most significant applicable standards if it is to be considered of world-class.

This type of book is long overdue. For those of us who are involved in the design of these devices, it has been a long road of learning. Many times, not having a concise source of readily available collection of design tips and general design information, we have had to learn the subtleties of these designs by experience. For those whose concern is the application and selection of the devices, there is a need for some guidance that is independent of commercial interests. There have been a number of publications on the subject, but most, if not all of them, use a textbook approach to treat the subject with a strict mathematical derivation of formulae. The material presented here is limited to