LINEAR ELECTRIC ACTUATORS AND GENERATORS

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I. Boldea
Polytechnic Institute, Timisoara, Romania

Syed A. Nasar
University of Kentucky

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CONTENTS

PREFACE

Linear electric actuators are electromagnetic devices capable of producing directly (without any linkages, etc.) progressive unidirectional or oscillatory short-stroke motion. The motion occurs because of the electromagnetic force developed in the actuator. Linear electric generators are also linear motion electromagnetic devices which transform short-stroke oscillatory motion mechanical energy into single-phase ac electrical energy. Just as a rotary electric machine may operate either as a motor or as a generator, a linear motion electromagnetic device may be designed to work either as an actuator or as a generator. From this standpoint, linear electric actuators and generators are the counterparts of a corresponding rotary electric machine. In general, however, linear electric machines have been associated with long linear progressive motion, such as in transportation and similar applications.

Whereas primitive linear electric machines have been in existence for a long time, since the 1960s there has been a great deal of interest in linear machines for various applications—especially transportation. Several books and numerous papers have been published on the subject in the recent past. However, the literature on linear electric actuators and generators is relatively sparse. Clearly, the potential applications of these devices are too numerous to mention here. Judged from the present trend, it would suffice to say that the field of linear actuators and generators may lead to an industry of "linear motion control" with a large worldwide market.

Much of the existing literature on the subject of linear actuators and generators deals with the principles of operation and performance calculations. Not much has been published on their control and detailed design methodologies. In this book, we present a unified treatment combining topologies of these devices with pertinent field distributions obtained by the finite-element method, state-space equations governing their dynamics and control, and detailed design methodologies. The book contains much new and original material developed by the authors.

In Chapter 1, we briefly review magnetic circuits, fields, and forces. In Chapter 2, we present an overview of linear electric actuators and generators (LEAGs). Basic definitions, terminology, and operating principles of LEAGs are introduced in this chapter. A classification of these devices is also presented in Chapter 2. Linear induction actuators are discussed in Chapter 3. Chapters 4 and 5, respectively, present linear permanent magnet and linear reluctance synchronous actuators. Linear switched reluctance actuators are described in Chapter 6, linear stepper actuators in Chapter 7, and linear electric generators (also termed linear alternators) in Chapter 8. We have not included "solenoids" here, as they are widely discussed in the literature. Throughout the book we have attempted to give a unified presentation, namely, basic construction and topology, field distribution, lumped parameter equivalent circuit, state-space equations, dynamics and control, followed by design examples.