Preface

The aim of this monograph is to present a concise conception of a new family of modern power frequency converters called matrix-reactance frequency converters. Currently used direct frequency converters, without DC electrical energy storage elements, have some disadvantages, such as the voltage transfer ratio limit of 0.866 in the majority of topologies and control strategies. Because of this these converters cannot be universally used in the industry. For example, in the case of the variable speed drive system for induction motors, a reduction in the supply voltage by 10 % means 20 % loss of torque capability, which is unacceptable in most applications. However, the advantage of this kind of converter is the elimination of a large and expensive DC energy storage. The converters presented in this book also do not have DC energy storage. What is more they enable the buck-boost voltage transformation. The topologies of the presented matrix-reactance frequency converters are based on the three-phase unipolar buck-boost matrix-reactance chopper with source or load switches arranged as in a matrix converter. This approach gives the possibility to obtain an output voltage greater than the input one (similarly as in a matrix-reactance chopper) and a frequency conversion (similarly as in a matrix converter). Nine new topologies of matrix-reactance frequency converters based on boost, buck-boost, Ćuk, Zeta or SEPIC structures are presented.

This monograph is composed of seven chapters, the organization of which can be understood as follows: the first chapter presents a short introduction on the state of the art and future trends in power frequency converters. The actual design tendencies in modern power electronic converters are also discussed here.

The second chapter presents a review of the most important AC–AC frequency converters without DC electrical energy storage as well as basic topologies of hybrid and with DC energy storage element converters. In this chapter the topologies, general operation and properties of this kind of converter are discussed. Mainly attention is paid to direct matrix converter topologies (voltage and current source matrix converters, multilevel matrix converters) and indirect matrix converters (sparse, very sparse and ultra sparse). A large part of the chapter is dedicated to explaining the design and function of a matrix converter. A matrix converter consists of nine bi-directional switches as the main power elements, and creates a variable load voltages with setting frequency. It is also referred as an “all-silicon solution”, because it does not have any large energy storage elements. The state of the art in matrix converter technology will be presented in this part of the text, with particular emphasis on control techniques, commutation methods and practical circuit realisation. This part also discusses a conception of converters based on matrix-reactance choppers, which are later called matrix-reactance frequency converters. A separate subchapter is devoted to hybrid frequency converters with small-sized DC electrical energy storage elements.

Chapter 3 describes the concept of a new family of matrix-reactance frequency converter topologies. In addition, a general description of such converters is also presented. The control techniques for these converters, based on the low frequency Venturini method, in particular, are exposed. Moreover, another concept of control strategies are suggested.

In Chap. 4 the averaged state space models of the discussed matrix-reactance frequency converters are described. It should be noted that the models, as a result of averaging, are continuously non-stationary ones, because the average value switch state function of matrix switches are time-varying. In order to obtain a stationary averaged state space model, a two-frequency form (dq) transformation is used. The aim of this chapter is to show stationary mathematical models of all matrix-reactance frequency converters. Furthermore, one part of the chapter includes the solution to the stationary averaged equations, based on stationary averaged models, in steady and transient states. Based on this solution the steady and transient state time waveforms of the averaged state variables are described, and steady-state characteristics are drawn.

Chapters 5 and 6 present some analytical, simulation and experimental test results. Analytical, test results are obtained from the solution presented in the previous chapter. Steady and transient state average time waveforms of currents and voltages in matrix-reactance frequency converters are shown. Furthermore the static characteristics are also presented. Additionally, a simulation verification of the first of two matrix-reactance frequency converters with buck-boost topology has been carried out with the use of a drive system with an inductor cage motor. A simulation study was carried out using the PSpice program. Furthermore, a 1 kVA matrix-reactance frequency converter with buck-boost topologies (two topologies) has been constructed to verify experimentally the concept. The obtained experimental and simulation test results confirm the theoretical analysis. The experimental test results are also shown in this section. Finally, in Chap. 7 conclusions and other comments are made.

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