Preface

Improving power density of converters, apart from conversion efficiency, has been one of the major drivers of modern developments in power electronics. Tracing the evolution of power electronics reveals that improvement in semiconductor devices, digital control with ever-increasing computational capability, improved packaging techniques combined with parallel development of converter topologies, switching schemes and advanced control techniques have kept on redefining the benchmarks with every passing day. The power converter which forms the core of any power electronic application is an electrical network involving only semiconductor switches and passive storage elements, with the latter largely contributing to the volume and weight of the converter. Therefore it is quite natural that, among competing candidates for a given application, the topology with the highest semiconductor to passives ratio—both in terms of component count and size—would offer the highest power density. For this specific possibility, the Matrix Converter—a generic name for any converter having only semiconductor devices in its power stage—demands focused investigation.

Matrix converters were proposed in the 1980s and almost immediately generated a lot of research interest, mostly in the domain of 3-phase AC-AC power conversion, and there has been several significant breakthroughs in modulation methods, multi-step commutation and space vector pulse width modulation. With respect to applications, academic and industrial research interest in Matrix Converters has been largely confined to motor drives. But since the last decade, there had been an emerging interest towards using Matrix Converters in power system applications. Most of these applications demand faster dynamic performance than the industrial drives, which have high plant inertia and thus do not require such response speeds. Absence of any intermediate energy buffering element makes the Matrix Converter a dynamically tightly coupled input–output unit and the overall system design, particularly controller design, challenging.

The research efforts which led to this book were a part of this effort to expand the application domain of Matrix Converter to power systems. Two target applications for synchronous systems have been addressed—regulated 3-Phase voltage supply and voltage sag mitigation. The objective of the book has been subsequently categorized into the following—developing a dynamic model which provides adequate design insight, filter design and devising a control scheme. The low-frequency dynamic model is first analysed for regulated voltage supply assuming balanced system. A linearized dynamic model is developed and it is shown that depending on the input power, input voltage and filter parameters a possibility of appearance of a set of right half zeros exist.

The design of filters is considered next. Apart from general issues like ripple attenuation, regulation, reactive current loading and filter losses, additional constraints which may be imposed by dynamic requirements and commutation are also addressed.

In the third stage, voltage controller design is detailed for 3-Phase regulated voltage supply. In the synchronous dq domain, output voltage control represents a multivariable control problem. The control problem is reduced to a single variable one while retaining all possible right half zeros, thereby preserving the internal stability of the system. Consequently, standard single variable control design technique has been used to design a controller. The analytically predicted dynamic response has been verified by experimental results. The system could be operated beyond the critical power boundary where the right half zeros emerge.

Finally, the developed control approach has been extended to voltage sag mitigation with adequate modifications. A 3-wire linear load has been considered. Both symmetrical and asymmetrical voltage sags have been considered.

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Design and Control of Matrix Converters
Regulated 3-Phase Power Supply and Voltage Sag
Mitigation for Linear Loads
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2017, XVI, 124 p. 75 illus., Hardcover
ISBN: 978-981-10-3829-7