Topic "Improved Modulation Techniques for Matrix Converters and Their Applications in Induction Motor Drives"

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ABSTRACT

One of the major industrial applications of power electronics is the control of motor drives, which are mostly dominated by converter fed induction motors. In such applications, features like energy efficiency, improved power quality, high power density and improved reliability are highly desirable. While most three-phase induction motor drives are conventionally fed through AC-DC-AC converters, this traditional approach is associated with a large footprint owing to an intermediate DC stage. DC link capacitor used as an intervening energy storage element, is not only bulky but also contributes to low system reliability. An interesting alternative in the form of matrix converters has been widely researched over the past two decades. Matrix converter belongs to the breed of direct AC-AC converters that facilitate multi-phase power conversion with smooth voltage control at unrestricted frequency, without any intervening DC link. It offers advantages such as improved power quality on source as well as load side, inherent bi-directionality, completely controllable input power factor, compact size and possibility for common mode voltage elimination. Owing to these features, matrix converters have been used in motor drives, wind energy conversion systems and aerospace applications.

In spite of a wide range of advantages, the industry acceptability of matrix converters has been limited. This is primarily because of difficulties in control, protection, and commutation. While some of these challenges have been overcome through research, others are still being worked upon. This thesis deals with the design and development of matrix converter fed induction motor drive, with complete protection and multi-step commutation. It elucidates some novel and improved modulation strategies for matrix converters, from the perspective of controlling induction motor drives. For the purpose of controlling three-phase induction motor drive, two topologies are selected viz. three-phase to three-phase matrix converter and single-phase to three-phase matrix converter. The challenges associated with the modulation of each topology are individually addressed, and their suitability is explored in the speed sensor-less control of three-phase induction motor drives.

Three-phase to three-phase matrix converter is the most commonly explored topology amongst multi-phase matrix converters. A large number of possible switching states, coupled with the simultaneous control of source and load side parameters, leads to complicated modulation. Space vector modulation remains one of the most popular control techniques which allows concurrent tracing of output voltage and input current space vectors. However, it is associated with high processor burden and complex implementation. Over the past decade, finite control set model predictive control (FCS-MPC) has been explored in the modulation of three-phase to three-phase matrix converter. It has especially shown promising results while achieving multiple objectives of source and load current control. However, it is associated with extensive mathematical modeling of load and input filter, besides performance dependence on processor strength. This thesis deals with certain improved and novel modulation approaches for three-phase to three-phase matrix converter that tend to simplify modulation and control. It deals with an improvised multi-objective model predictive control strategy that combines FCS-MPC and space vector modulation to achieve enhanced system performance at higher sample times and limits switching frequency variations. Furthermore, a unique predictive delta sigma modulation (PDSM) technique is proposed, that is simple and intuitive to implement, with significantly reduced processor burden and enhanced system performance as compared to previously documented techniques. PDSM is also explored in common mode voltage elimination for three-phase to three-phase matrix converter based systems. Speed sensor-less vector control is implemented for commonly used 21 states of the converter using PDSM technique with a full order predictive observer for wide range of speed estimation. Moreover, the matrix converter fed induction motor drive is modulated using only six common mode voltage eliminating states in order to present a more reliable drive solution, while tapping all other advantages of the converter, over a wide range of rotor speed. The speed sensor-less drive is also tested for hysteresis based direct torque control (DTC) and constant switching frequency based DTC, with suitable choice of speed observers. All control algorithms are developed in Matlab/Simulink environment, followed by experimental verification on a four layer PCB prototype of matrix converter based induction motor drive.

In order to facilitate the control of a three-phase induction motor on a single phase supply, the use of single-phase to three-phase matrix converter is advocated. This topology has not garnered significant interest of the research community owing to a poor voltage conversion ratio, and severely compromised harmonic performance due to instantaneous power mismatch between single-phase input and three-phase output. This thesis explores the optimum use of single-phase to three-phase matrix converter for low speed sensor-less control of three-phase induction motor drive from a single-phase supply. The delta sigma technique is demonstrated for enhancement of motor current quality in the low speed region, while compromising on the quality of source current. Further, a multi-objective FCS-MPC technique is demonstrated and compared with other modulation schemes, to achieve a suitable trade-off between the power quality on the grid side versus that on the motor side. All modulation techniques are experimentally validated on single-phase to three-phase matrix converter fed inductive load followed by demonstration with speed sensor-less control on a three-phase induction motor drive.