Abstract

Power electronic converters have become more prevalent in the last four decades to deliver the demand of industrial applications and better utilize renewable power. Among the power electronic converters, AC-AC converters occupy a significant portion. Broadly, AC-AC converters can be classified into two types, one with energy storage and another without energy storage, called matrix converters (MC). Converters with energy storage, such as diode bridge cascaded voltage source inverters and voltage source back-to-back converters, are more standard and adopted in the industry. Matrix converters have evolved by reducing the energy storage elements and improving the input switching characteristics. Matrix converters have always been futuristic, with desirable features like input power factor control, high power density, high efficiency, and extended service lifetime. On the other side, it has a restricted voltage transfer ratio, transfer of reactive power capability, and higher common mode voltage (CMV). To cater the above limitations and retain the inherent features of matrix converters, researchers are integrating impedance networks with matrix converters, leading to a classification of hybrid matrix converters.

In this thesis, a proposition has been made to investigate an ultra sparse matrix converter (USMC) topology, a fine-tuned version of a matrix converter characterized by a minimum number of semiconductor switches. Voltage gain limitation and higher common mode voltages are the main issues of USMC. In this work, 1) common mode voltage has been reduced with the help of auxiliary shoot-through switches. 2) A modified space vector modulation technique is proposed to define new zero vectors. This would cause soft switching at the rectifier side of the USMC and regain the modulation index range $0 < m < 1$, similar to a conventional space vector modulation technique.

To achieve a voltage transfer ratio more than unity, quasi Z source and switched

boost networks are integrated at the DC-link section of USMC.

An improved space vector modulation technique is developed for the quasi Z-source ultra sparse matrix converter (QZS-USMC) to achieve high voltage gain with minimum common mode voltage (CMV) and reduced ripple in the inductor current by proper arrangement of switching states in a switching cycle. Furthermore, a switched boost ultra sparse matrix converter (SB-USMC) is proposed with shoot-through immunity and enhanced voltage gain using fewer passive elements. This converter has produced a balanced output voltage even with an unbalanced input supply. A three vector space vector modulation (TVSVM-II) technique is also developed to reduce the peak magnitude of the CMV in SB-USMC.

The proposed converters with advanced modulation techniques are potential solutions for the existing line of converters in wind energy systems, where a low voltage variable speed generator feeds power to the higher voltage fixed frequency grid. The proposed solution may also used for AC drive applications, where variable voltage and frequency are required.

Comprehensive analytical derivations and simulation results have been carried out to investigate the operation of the proposed converters. The performance of the proposed converters is then compared with conventional converters. The FPGA (Artix7100CGS324-1) controller is used for the real-time processing of signals. The operation of the converters has been experimentally validated using a laboratory prototype.