CHAPTER 2

LITERATURE SURVEY

The key feature of a direct AC-AC converter is the ability to perform directly AC-AC power conversion without the need of energy storage elements. The cyclo-converter was the first direct AC-AC converter; that can construct low-frequency AC output voltage waveforms from successive segments of an AC supply of a higher frequency. However, due to the naturally commutated device characteristic, this converter topology has limited the output frequency range, the input power factor, and high distortion in input and output waveforms (Mohan et al. 2003). With the rapid development of fully controlled power semiconductor devices, a force commutated cyclo-converter or ‘matrix converter’ was developed as a promising technique for direct AC-AC power conversion (Neft & Schauder 1992). Using the fully controlled bi-directional switches to connect the inputs directly to the outputs, the matrix converter topology can generate variable output voltages with unrestricted frequency from an AC voltage supply.

The matrix converter can also be able to produce sinusoidal supply currents and modifiable input power factor irrespective of the load. Most importantly, the removal of the DC-link energy storage element enables the matrix converter topology to have a more compact design, which is an advantage in applications such as aerospace (Wheeler et al. 2002). Matrix converter topologies can be divided into two types: the direct matrix converter and the indirect matrix converter (also referred to as “dual bridge matrix converter” (Robson et al. 2003), “sparse matrix converter” Wei et al. 2002 or
“two-stage matrix converter” (Kolar et al. 2002). By applying appropriate modulation strategy, such as Venturini method (Klumpner & Blaaberg 2002 & Alesina & Venturini 1988) or space vector modulation (Huber et al. 1989, Huber et al. 1992, Casadei et al. 1993, Huber & Borojevic 1995, Casadei et al. 2002), the direct matrix converter can generate high-quality sinusoidal input and output waveforms. The indirect matrix converter topology is the physical implementation of the indirect modulation method (Casadei et al. 2002).

In some applications, the indirect matrix converter may be preferred to the direct matrix converter due to simpler and safer commutation of switches (Wei & Lipo 2001). The possibility of further reducing the required number of power semiconductor switches (Nielsen et al. 1996) and the possibility to construct complex converter topology with multiple inputs and output ports (Kolar et al. 2002). Matrix converter topologies have some drawbacks. Besides requiring a high number of power semiconductor devices, the maximum load voltage of the matrix converter is limited to 86% of the supply voltage (Klumpner & Blaaberg 2002). Having no energy storage element, the load side of the matrix converter is susceptible to supply-side disturbances, such as unbalanced supply voltages, voltage sags, dips, harmonics, etc., leading to output voltage distortion and a reduction in the voltage transfer ratio.

Despite these drawbacks, the significant advantages of the matrix converter have encouraged extensive research into implementing the topology. Different techniques have been proposed Nielsen et al. (1996), Blaabjerg et al. (2002), Wei et al. (2003), Klumpner et al. (2006) to maintain the load voltage quality and maximum voltage transfer ratio of the matrix converter topology even during the supply-side disturbances. The motor connected to matrix converter can be designed to reach low flux at maximum voltage transfer ratio Klumpner et al. (2002). Various control based on
modulation techniques for output voltage regulation while maintaining power quality at the input side of the converter has been applied to different kinds of MCs, as has been reported in Rodriguez (1987) and Itoh et al. (2004), Yoon & Sul (2007).

SVM has been proposed in Huber & Borojevic (1995) & Casadei et al. (2002), Blaabjerg et al. (2002), Simon et al. (2002). The space vector approach is based on the direct space vector representation of input and output voltages and currents. Among the 27 possible switching configurations available in three-phase MCs, only 21 are used in the SVM algorithm. The first 18 switching configurations determine an output voltage vector and a current input vector, having fixed directions.

The SVM algorithm for MCs has the inherent capability to achieve full control of both the output voltage vector and the instantaneous input current displacement angle Huber & Borojevic (1995), Blaabjerg et al. (2002) Helle et al. (2004), Ormaetxea et al. (2011). The two-stage SVM method Cardenas-Dobson et al. 2011 is a variation of the classic SVM technique which has some important features such as overmodulation, but this method is no longer used.

The matrix converter is the force-commutated version of the cycloconverters Huber & Borojevic (1989) which overcomes the disadvantage of the conventional cyclo-converter such as the limitations in the frequency conversion, rich output voltage harmonics and increased number of switches Rashid (2005), Fa-Hai Li et al. (1994). The matrix converters can be classified as direct and indirect type matrix converters. The indirect or the sparse matrix converter is a cascade of the controlled rectifier and inverter topologies without a DC link in between Ziogas et al. (1986). Both the topologies directly interconnect two independent multi-phase voltage systems at different frequencies. In this research, the CMC topology is chosen and is
analyzed for its performance for changes in its topology and with a different pulse width modulation (PWM) techniques.

The implementation of the dead-time commutation DTC in matrix converters leads to the interruption of inductive currents due to the absence of an absolute path. Use of such technique in matrix converters requires snubber circuits to provide an alternate path to the inductive currents Sunter & Clare (1996) which increases the complexity and the size of the converters. Soft switching techniques have been investigated in many converter topologies for reducing the switching losses. However, the implementation of soft switching techniques in matrix converters Sunter & Clare (1996) increases the component count and complexity of the converters.

Several modulation algorithms are reported for matrix converters in Marcks (1995) to achieve different control objectives. The over-modulation operation has been described as a nonlinear operation Holtz et al. (1993) since the output waveform of the converter does not follow the original sinusoidal reference waveform in the regions of higher magnitudes. The over-modulation in the DC-link converters has been widely described in the literature Bolognani & Zigliotto (1996), but only a few papers describe the specific effects of overmodulation operation of the matrix converter Bolognani & Zigliotto (1996). The author discusses four ways of operating the matrix converter in overmodulation (i) output side overmodulation, (ii) input side overmodulation with power factor control, (iii) input side overmodulation without power factor control and (iv) simultaneous output and input side overmodulation. Using the overmodulation technique, the theoretical voltage limit of the converter can be increased to 105% of the input voltage. It has been proved in Thuta (2007) that some lower order harmonics are generated at the output voltage and the input current by the overmodulation operation Mahlein et al. (1999).
Overmodulation operation of the matrix converter might cause the resonance of the line side filter. This might damage the converter if not controlled properly. Thus, it was concluded in Wiechmann et al. (1997) that it is not advisable to operate the matrix converter under overmodulation for a long time but for a short period, if demanded, for the ride-through operation. One of the desirable characteristics of the modern drives is its ride-through capability. During ride-through, to magnetize the motor windings and to feed the control circuits, the drive utilizes energy from the load inertia. Conventional converter achieves this by maintaining a constant voltage in the DC-link capacitor in the AC-DC-AC converters Wiechmann et al. (2002), Narayanan & Ranganathan (2002), Kim & Sul (2001). However, the matrix converters are an array of controlled bidirectional switches without the DC-link capacitor, and these are highly susceptible to voltage disturbances such as voltage sags, voltage swells, and momentary power interruption. A new ride-through strategy for the matrix converter developed by Zhang et al. (2001) uses the zero vectors of the matrix converter and the clamp circuit to ride-through small interruptions.

In Wiechmann et al. (1997) an alternative strategy is proposed that enable the converter to ride through the voltage sags and enforces constant V/F operation with the minimum reduction in the speed. Later, a new approach was presented in Jounne et al. (1999) that modified the topology of the matrix converter with three additional unidirectional switches and a ride-through capacitor. The effect of the unbalance on the converter performance is a vital aspect of determining the overall performance of the variable speed drive, which is fed by a converter.

The matrix converter, being a direct frequency conversion system, the unbalance at the utility side is immediately reflected on the load side and generates unwanted lower order input/output harmonic currents Klumpner et
that may resonate with the input filter causing damage to the converter, if uncontrolled. Therefore, research has been directed to investigate and compensate for these effects of input voltage disturbance. In Narayanan & Ranganathan (2002) it is highlighted that a balanced and sinusoidal output voltages were produced even when the input voltages were unbalanced.

In Enjeti & X Wang (1990) the input current harmonic content and the limits of the voltage transfer ratio of matrix converter under unbalanced conditions were determined analytically for different operating conditions.

In Nguyen & Hong-Hee Lee (2012) the line side voltage conditions with high order voltage harmonic components are analyzed. However, it was concluded in all these techniques that the input current harmonics could not be reduced when compensated for the output harmonics under abnormal conditions of the input voltage. The high-frequency common mode voltage generated by the power converters are reported to cause potential damage to the shaft and the bearings of the electric motors. The reduction of the common mode voltage in matrix converters using proper switching sequence has been reported in Casadei et al. (1998), Zhang et al. (2001).

Recently, Nguyen & Hong-Hee Lee (2012) presented the elimination of the common mode voltage in the matrix converter fed open-ended induction machine. New topologies that are different from the conventional matrix converters, named as indirect matrix converter topologies, consisting of a rectifier/ inverter circuit without a DC-link were proposed in Cha & Prasad (2003) along with their PWM control and commutation procedures. Zero current commutation methods of the line side switches were also discussed in detail in Gupta et al. (2010) for the indirect matrix converter topologies to reduce the complexity involved in the four-step commutation of bidirectional switches in the matrix converters.
These topologies are referred as the “sparse matrix converters”. These sparse matrix converters were classified as (i) Simple Sparse Matrix Converter (SSMC) with 15 switches, (ii) Very Sparse Matrix Converter (VSMC) with 12 switches and (iii) Ultra Sparse Matrix Converter (USMC) with nine switches Wiechmann et al. (1985). The VSMC and the USMC were designed based on the fact that the DC link current only flows in one direction. This constraint makes the VSMC and the USMC not applicable for regenerative operation. Holtz & Boelkens (1989) experimentally confirmed that a matrix converter with only nine switches could be effectively used in the vector control of an induction motor with high-quality input and output currents.

The compactness of the matrix converter suggested the possibility to integrate the converter and the motor in a single unit, to reduce the costs and to increase the overall efficiency Meng Yeong Lee (2009). Matrix converters find their application in the field of wind power generation in the form of full power converter topologies, and partial converter topologies for the doubly fed induction generators control Neft & Schauder (1992), Itoh et al. (2005). An increasing number of papers Zhang et al. (1997), Lillo (2006) investigating the advantages/limitations of the use of matrix converters in aircraft are also being reported.

Lopez et al. (2014), show the theoretical development of predictive control strategy for multi-drive systems to control torque, flux and minimizing the reactive input power through a 3x6 IMC, under both balanced and unbalanced grids. The system achieves a good minimization of the reactive input power. Note that in unbalanced grid conditions, the input current is distorted while the system minimizes the reactive input power as expected to achieve constant output power.
Mostafa et al. (2015), presented an extension of the carrier based PWM technique applied for the IMC to adapt the SMC. An integrated control system is proposed for the SMC to interface PMSG based wind turbine unit with the power grid. The inverter stage is controlled to extract the maximum power from the wind turbine unit by regulating the speed of the PMSG at the set value determined by the MPPT.

Zhuang Xu (2015) an AC-DC matrix conversion has been derived. For the proposed AC-DC converter, a new type of closed-loop control strategy is proposed based on the indirect space vector modulation algorithm. According to the closed-loop control strategy, experiments have been carried out to verify the feasibility of closed-loop control of the proposed AC-DC matrix converter, which has proved the effectiveness of the proposed system.

In Han Zhao & LI Sheng-min (2015) show the correctness and effectiveness of the new SVPWM modulation strategy in improving the voltage transfer ratio and reducing the switching losses. Compared with the traditional indirect space vector modulation strategy, the new type of reconfigurable matrix converter SVPWM strategy has the advantages. In Javier Riedemanna et al. 2016 A topology based on indirect matrix converter to drive open-ended winding AC machines have been presented. Two modulation strategies have been used for the input rectifier, depending on the output voltage requirement. One modulation strategy aims for a maximum positive DC voltage, and the other modulation strategy aims for a reduced positive DC voltage.