Matrix Converter Based on Asymmetric Regular Sampling Method SPWM Control Strategy

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Abstract

In this paper, the Matrix converter can be viewed as AC-DC-AC converter, the asymmetric regular sampling method SPWM control technique is applied in the control of matrix converter, the asymmetric regular sampling method SPWM control strategy of matrix converter, 48 allowed switch combinations and Four-Step Current Commutation method is presented. Based on Matlab/simulink the simulation of the matrix converter with such strategy is carried out. Inductive load simulation is carried out on the matrix converter prototype. The simulation results verify the workability of the asymmetric regular sampling method SPWM strategy for matrix converter.

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Keywords: Asymmetric regular sampling method; SPWM control strategy; Matrix converter

1. Introduction

Matrix converters have been recognized to have many advantages due to its compact topology[1]. It is believed that the matrix converter can have significant advantages over the traditional dc link converter in many areas since it is possible to eliminate the dc link capacitor. Compared to the PWM-VSI, the matrix converter provides a. sinusoidal input and output waveforms; b. bi-directional power flow; c. controllable input power factor and linearly modulated output voltage [2]; d. the filter design issues are complex and a decoupling between input and output distortions is to some extent limited due to the absence of the dc-link capacitor[3-5].

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2. Analysis of the Asymmetric Regular Sampling Modulation

![Fig.1. Matrix converter topology](image)

The matrix converter topology is shown in Fig.1, where each of the nine switches, \(S_{ij}\) \((i,j=1,2,3)\), represents a bi-directional configuration. The basic matrix converter circuit can be seen as the combination of two parts. Its AC-DC-AC equivalent circuit is showed in Fig.2 \([6-9]\). In order to improve utilized efficiency of the input voltage, only the two line-line input voltages with the highest amplitudes are used.

### 2.1. Asymmetric regular sampling method SPWM control technique

The asymmetric regular sampling method SPWM control technique is illuminated in Fig.3. As shown in Fig.3, the following equations can be derived.

\[
t_{off} = T_C / 4 \times (1 - m \sin \omega_s t_{1i}) \tag{1}
\]

\[
t_{on} = T_C / 4 \times (1 + m \sin \omega_s t_{1i}) \tag{2}
\]

\[
t^{'}_{off} = T_C / 4 \times (1 - \sin \omega_s t_{2i}) \tag{3}
\]

\[
t^{'}_{on} = T_C / 4 \times (1 + \sin \omega_s t_{2i}) \tag{4}
\]

where \(t_{off}\) and \(t^{'}_{off}\) are off-duty time, \(t_{on}\) and \(t^{'}_{on}\) are on-duty time. Using that (1)-(4), the on-duty time \(t_{pu}\) and the off-duty time \(t_{ofi}\) in per cycle \(T_C\) can be derived

\[
t_{pu} = T_c [1 + m (\sin \omega_s t_{ui} + \sin \omega_s t_{2i}) / 2] / 2 \tag{5}
\]

\[
t_{ofi} = T_c [1 - m (\sin \omega_s t_{ui} + \sin \omega_s t_{2i}) / 2] / 2 \tag{6}
\]

where \(T_c\) is the triangular wave (carrier) waveform cycle, \(\omega_s\) is the sine wave (modulating) waveform angular speed, \(m = U_{Mm} / U_{Cm}\) is defined as the modulation index, \(U_{Mm}\) is the amplitudes of the sine wave (modulating) waveform, \(U_{Cm}\) is the amplitudes of the triangular wave (carrier) waveform; \(t_{ui} = T_c / 4 + (i-1)T_c\), \(t_{2i} = 3T_c / 4 + (i-1)T_c\) \((i=1,2,\cdots, N_{CM})\). \(N_{CM}\) is the modulation depth.
2.2. Vector time intervals

In per cycle of the PWM, the relationship between the triangular wave (carrier) $U_c$ and tri-phases sine wave (modulating) $U_{Ma}, U_{Mb}, U_{Mc}$ is shown in Fig.4. As shown in Fig.4, there are seven switch combinations in every PWM cycle. When $U_{Ma} > U_{Mb} > U_{Mc}$ and $U_{ab}$ is the two line-line voltages with the highest amplitudes, the seven switch combinations logic are $000 \rightarrow 100 \rightarrow 110 \rightarrow 111 \rightarrow 110 \rightarrow 100 \rightarrow 000$. Look up in the Table 1, Each switch combination of the matrix converter can be gotten. In this case, the actual switch combinations of the matrix converter are $(S_{12}, S_{22}, S_{32}) \rightarrow (S_{11}, S_{22}, S_{32}) \rightarrow (S_{11}, S_{21}, S_{32}) \rightarrow (S_{11}, S_{21}, S_{31}) \rightarrow (S_{11}, S_{21}, S_{32}) \rightarrow (S_{11}, S_{22}, S_{32})$ and the on-duty time of each switch combination is $(t_{offA}) \rightarrow (t_{offB} - t_{offA}) \rightarrow (t_{offC} - t_{offB}) \rightarrow (t_{pcC} - t_{offC}) \rightarrow (t_{offB} - t_{offA}) \rightarrow (t_{offA})$. Using that (1)-(6), the value of $t_{offA}, t_{offB}, t_{offC}, t_{pcC}, t_{offB}, t_{offA}$ can be gotten. In every PWM cycle, there are 7 switch combinations and every switch is on duty two times. The others switch combination of the matrix converter can be gotten in the same way.

2.3. Four-Step Current Commutation

In order to consider the current commutation in matrix converters, it is only necessary to look at a two-phase to single-phase converter, as shown in figure 5. Assume that switches S1p and S1n are on, S2p and S2n are off, and that we want to reverse this condition. Further assume that the load current is flowing into the load, as shown in Figure 6. In this case, we gate switch S1n off (because it is carrying no current), followed by switch S2p gated on (this produces no phase-to-phase short, since S1p and S2p both conduct current in the same direction), followed by switch S1p gated off (the current conduction path now has to be through S2p), and finally, we gate switch S2n on. If the current direction was in the opposite direction, then the correct sequence would be S1p off, S2n on, S1n off, and S2p on. This commutation sequence is shown in the timing diagram in Figure 6.
3. System Simulation

To validate the functionality of the proposed the Asymmetric regular sampling method SPWM approach and to compare the different modulation schemes in the time domain, a simulation system was built based on Matlab/simulink.

When the Input frequency is 60 Hz, Output frequency is 40 Hz and the Modulation index is 0.8, the output line-line voltage $U_{ll}$ simulated waveform is shown in Fig. 7 and the stator current shows in Fig. 8.

4. Conclusions

This paper has presented a new modulation scheme for three-phase matrix converters. The new modulation scheme is applicable whenever the output voltage reference is below the input voltage. To evaluate the proposed modulation method and matrix converter modulation schemes in general, the simulated results are shown. The output voltages, the stator current and the performances of the load induction motor are superior the DC link converter. The proposed system has stable operation and the system performs correctly in different conditions of motor operation.
References


