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Single Phase Matrix Converter as a Frequency Changer with Sinusoidal Pulse Width Modulation using Matlab

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Abstract

This paper presents work on modeling & simulation of single-phase matrix converter (SPMC) as a frequency changer modulated by the Sinusoidal Pulse Width Modulation (SPWM) subjected to passive load condition. The model was implemented using MATLAB/Simulink with the Sim Power System Block Set. The Insulated Gate Bipolar Transistor (IGBT) was used for the switching device. Safe commutation strategy was implemented to solve switching transients with sample verification on results.

Keywords: Sinusoidal Pulse Width Modulation (SPWM), Insulated Gate Bipolar Transistor (IGBT), Single-Phase Matrix Converter (SPMC), Frequency Changer.

Introduction

The Matrix converter (MC) offers possible "all silicon" solution for AC-AC conversion, removing the need for reactive energy storage components used in conventional converter system. The use of direct AC-AC converter based on matrix converter topology is restricted due to inherent limitations[3]. One of those limitations is the absence of the natural free- wheeling path afforded in conventional converter topology through the use of diodes. In this paper a simple commutation strategy for implementation in single phase matrix converter provides the required free-wheeling operation similar to those available in other converter topologies is proposed.

The commutation scheme establishes a current path for energy to flow during dead-time, thus avoiding the generation of voltage spikes. The aim of this paper is to describe involved in the implementation of the Single-Phase Matrix Converter (SPMC) as an AC-AC converter when subjected to passive load conditions[5]. The output voltage was synthesized using the well-known Sinusoidal Pulse Width Modulation (SPWM) as suggested by Firdaus with the IGBT as the power switching devices. Safe-commutation strategy was implemented to solve switching transients. The MATLAB/Simulink (MLS) with the SimPower System (SPS) Block Set are used in this instance providing a flexible and versatile simulation environment.

Single Phase Matrix Converter (SPMC)

The Matrix Converter is a forced commutated converter which uses an array of controlled bidirectional switches as the main power elements to create a variable output voltage system with unrestricted frequency[2]. The SPMC requires 4 bi-directional switches each capable of conducting current in both directions, blocking forward and reverse voltages .It requires the use of bidirectional switches capable of blocking voltage and conducting current in both directions. The IGBT were used due to its popularity amongst researchers that could lead to high-power applications with reasonably fast switching frequency for fine control, whilst the diodes provides reverse blocking capabilities to the switch module.

The single-phase matrix converter(SPMC) used in this paper is as shown in Fig 1.with common emitter anti-p arallel IGBT, diode pairs which is capable of conduct current in both directions, whilst at the same time it is capable for blocking voltages.

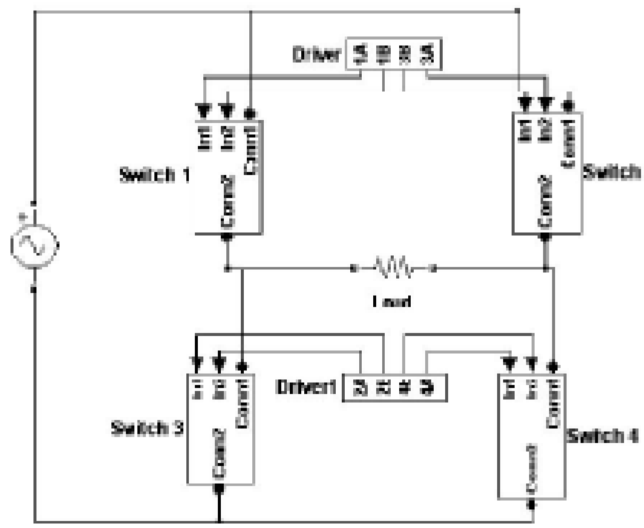

Figure 1: Main model of SPMC.

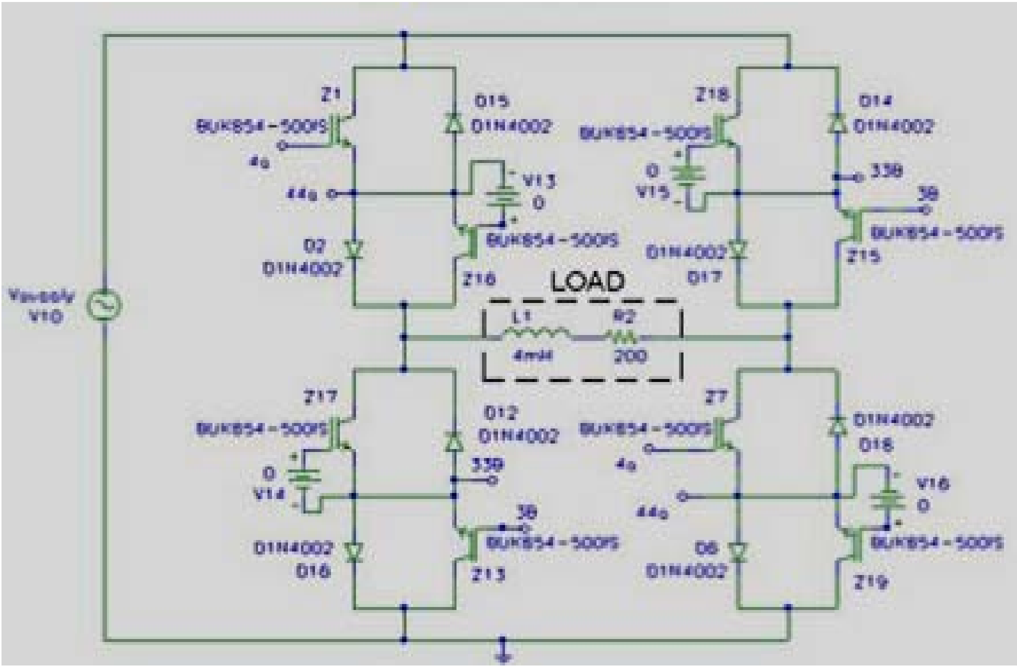

Figure 2: Design of SPMC.

Thus the Single phase Matrix converter is given as shown in above fig 2.

Sinusoidal Pulse Width Modulation

In state-1 the devices s1a and s4a are turned on and the flow of current from right to left.

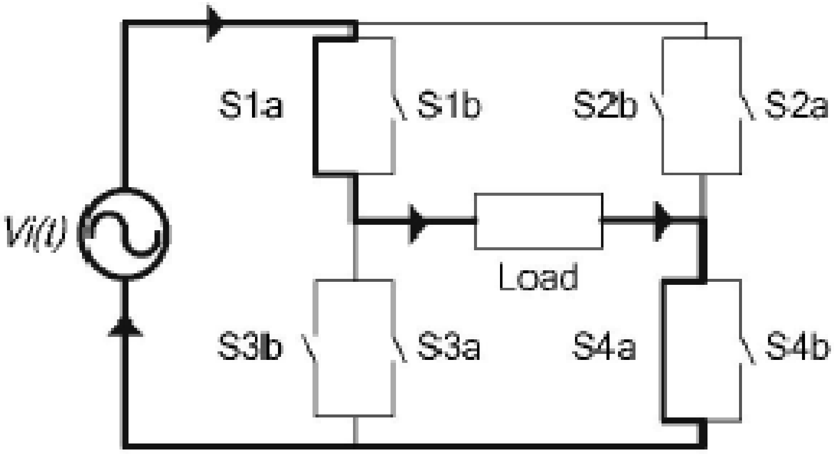

Figure 3: State1 AC input (positive).

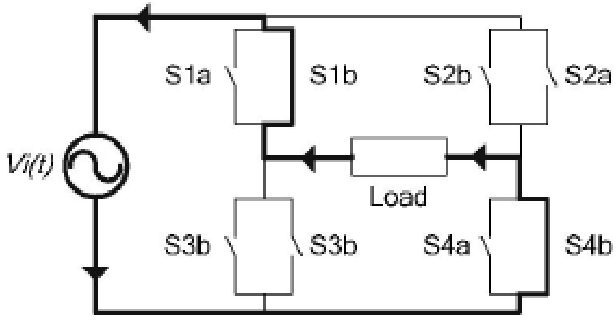

Figure 4: State2 AC Input (negative) .

In state-2 the devices s4b and s1b are turned on and the flow of current from left to right.

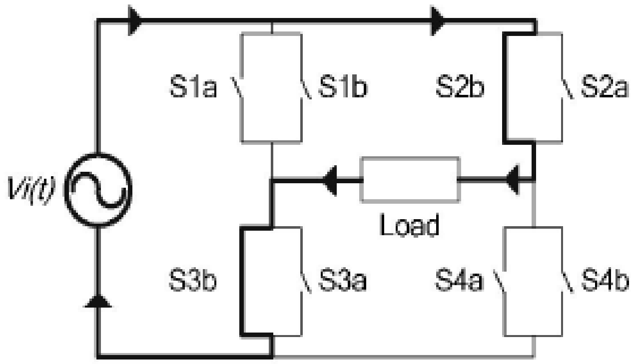

Figure 5: State3 AC Input(positive).

In state-3 the devices s2a and s3a are turned on and the flow of current from right to left

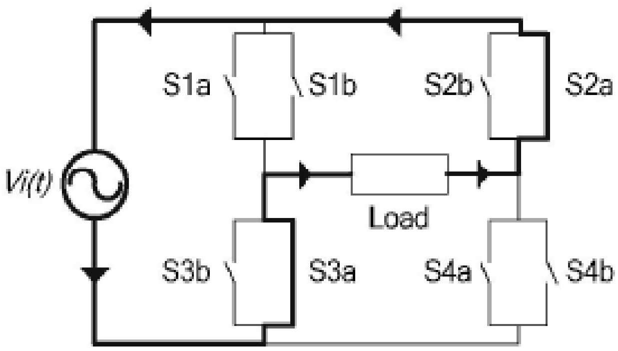

Figure 6: State4 AC Input (Negative).

In state-4 the devices s3b and s2b are turned on and the flow of current from left to right.

Then the safe switching sequence of control strategies are given as shown below in the table.

Switches	S1a	S1b	S2a	S2b	S3a	S3b	S4a	S4b
Positive cycle	PWM	OFF	OFF	OFF	OFF	ON	ON	OFF
Negative cycle	ON	OFF	OFF	ON	OFF	PWM	OFF	OFF

Figure 7: Condition of Switches in positive & negative cycle.

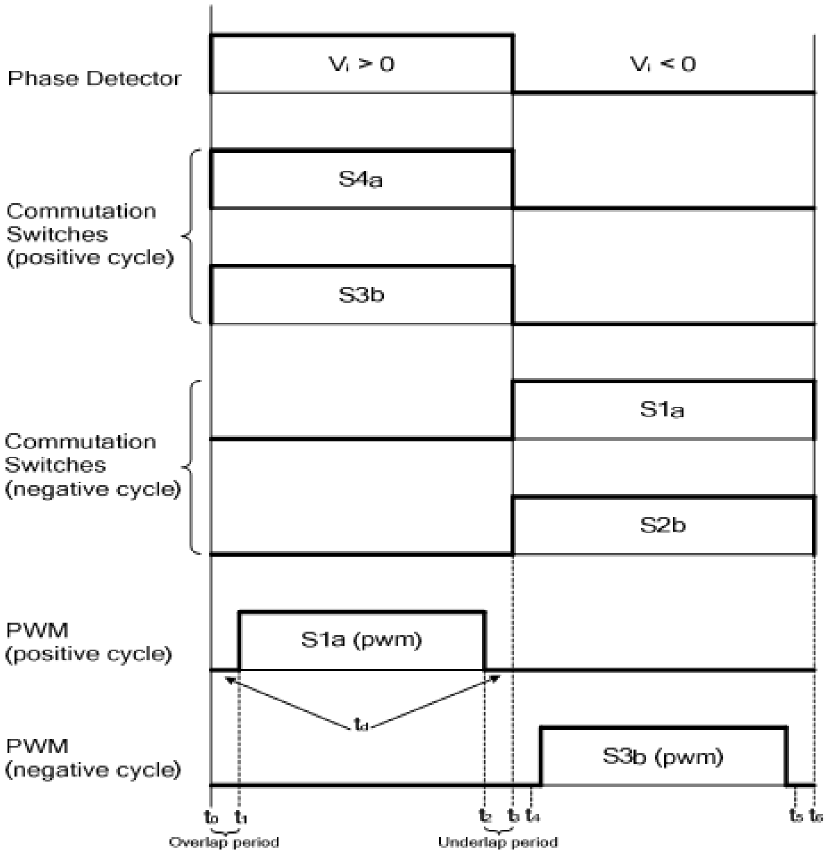

Figure 8: Switching Time of Matrix Converter.

The sine wave used as a reference to generate the PWM output is divided into 4 symmetrical sections A, B, C & D. Observe B can represent a mirror A. C & D can mirror the positive cycle of A & B. Hence we could develop B, C & D by using section A to generate respective representations; thus could reduce representations to almost 25% of the total required data to produce the reference.

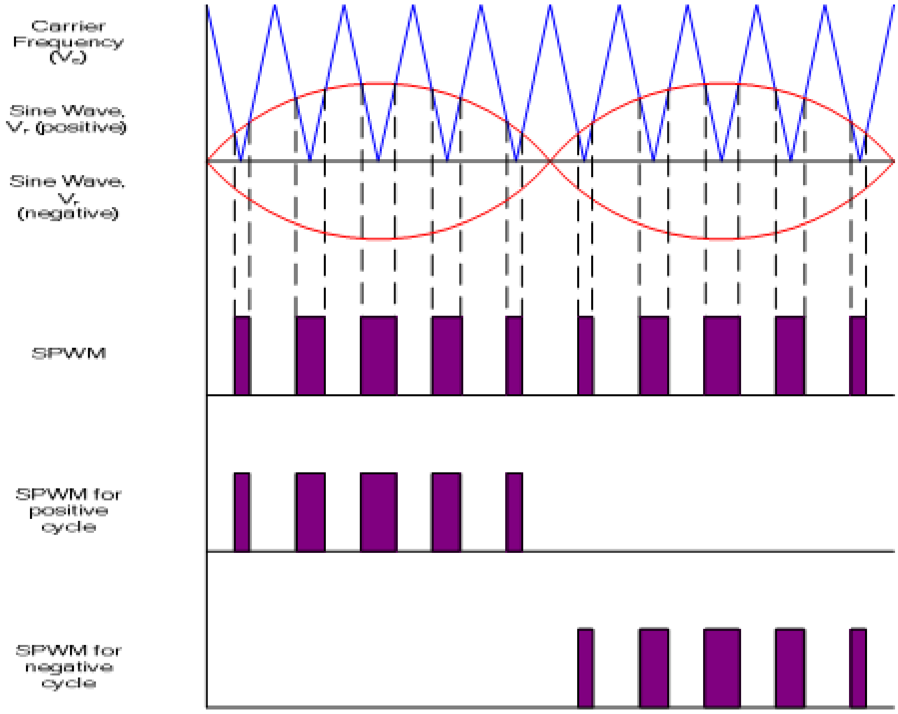

Figure 9: Formation of SPWM.

The output frequency is synthesized in multiples of 50Hzinput frequency (say 50Hz, 100Hz and 150Hz). The sequences of switching are dependent on the time interval and state of the driver circuit, represented by table 1 (For one cycle).

Commutation Strategy

The sequences of switching and commutation switching Strategies are dependent on the time interval and state of the driver circuit as tabulated in below table (for one cycle)[1]. There are total of four different Switching states capable of being used in various combinations to produce the desired effect. This method allows commutation between switching states without producing those damaging spikes.

Input Frequency	Output Frequency	Time Interval	State	Switch "ON"	Commutation Switch "ON"
50 Hz	50 Hz	1	1	S1a & S4a	S2a
		2	2	S1b & S4b	S2b
	100 Hz	1	1	S1a & S4a	S2a
		2	3	S2b & S3b	S1b
		3	4	S2a & S3a	S1a
		4	2	S1b & S4b	S2b
	150 Hz	1	1	S1a & S4a	S2a
		2	3	S2b & S3b	S1b
		3	1	S1a & S4a	S2a
		4	2	S1b &S4b	S2b
		5	4	S2a & S3a	S1a
		6	2	S1b & S4b	S2b

Figure 10: condition of switches at different frequencies.

Hence the above table shows the switching sequences and the condition of various frequencies with their intervals[6].

Simulink Circuit

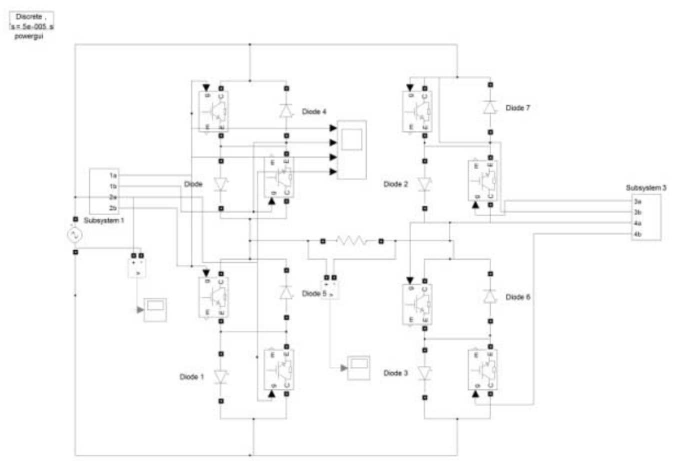

Figure 11: Matlab circuit.

The above circuit shows the simulink model for single phase Matrix Converter[4]. The below figure shows the input waveform for the circuit for the MATLAB circuit. Then the output will be given as shown below in the figure.

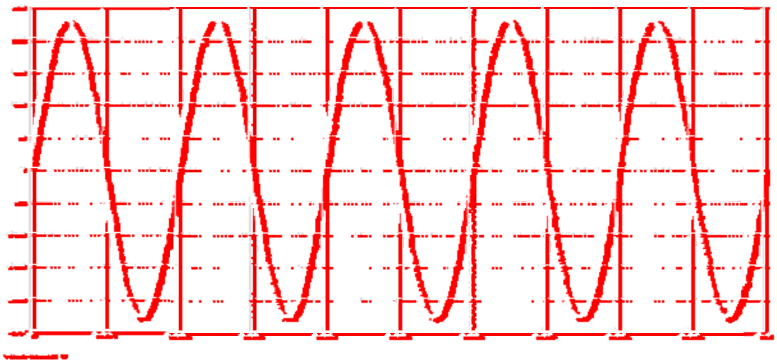

Figure 12: Input waveform to the Simulink Circuit.

The simulation parameters used for the input waveform are given as mentioned in above table.

Input Source (AC)	50 V_{rms}
Reference Frequency signal (f_r)	50 Hz, 100 Hz and 150 Hz
Carrier Signal (f_c)	5 KHz
Sample Modulation Index (m_i)	0.5 and 1.0
Load	R = 50 Ω

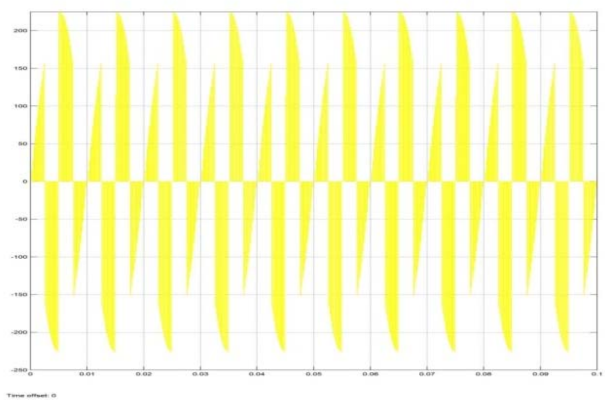

Figure 13: Output waveform after Simulation.

Thus the output waveform is obtained for a carrier frequency of example of 50Hz.

Conclusion

The modeling and simulation of the Single-Phase Matrix Converter (SPMC) as an AC-AC converter with passive load conditions had been presented[7]. The output voltage was synthesized using the well-known Sinusoidal Pulse Width Modulation (SPWM) with the IGBT as power switching devices. Safe-commutation strategy was implemented to solve switching transients. The MATLAB/Simulink (MLS) with the SimPower System (SPS) Block Set are used in this instance in providing a flexible and versatile simulation environment.

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