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Design and Simulation of Single Phase Matrix Converter as a Universal Converter

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Abstract

This paper represents a single phase matrix converter which is designed, simulated and analyzed as a universal converter where different power conversion topologies such as AC-AC, DC- DC & DC- AC with regenerative capability are possible. The desired output for each converter topology was obtained using Matlab-Simulink. Thus SPMC as a single converter capable of all sorts of power conversion is analyzed.

1. Introduction

Matrix converter is the most versatile converter which is basically an AC-AC converter in which the frequency, amplitude and number of phases of the output voltage can be varied. The same circuit can also be used for DC-AC, AC-DC and DC-DC conversions. It has several advantage including sinusoidal output voltage and input current, unity input power factor, inherent regenerative capability and absence of dc link which makes it suitable for different industrial applications. In this paper single phase matrix converter is analyzed for all possible modes of conversions including AC-AC conversion, DC-AC conversion with regenerative action, and DC-DC conversion. SPMC is introduced by Zuckerberger in 1997. It has step-up/down frequency transformation capability and the voltage will get stepped down. But for applications like traction rectifier, it is a desirable characteristic and the use of SPMC will reduce considerably the weight of the power transformer [1].

SPMC consists of two legs and four bidirectional switches. Since no monolithic bidirectional switches are available, two antiparallel IGBT-Diode pairs can be used.

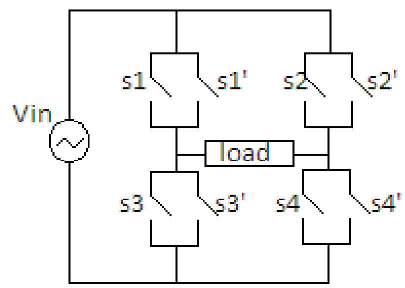


Fig 1 Single Phase Matrix Converter

The transfer function of the matrix converter is represented as T, input voltages Vin and Vout as the output voltage. The relation between input and output voltages of a matrix converter can be expressed as,

$$Vout = T \times Vin \qquad (1)$$

Number of methods is there in practice for the modulation of matrix converter. In this paper sinusoidal pulse width modulation (SPWM) is used. In SPWM sinusoidal reference signal is compared with triangular carrier and gating pulses are generated corresponding to the cross over points of both. Amplitude of the output voltage depends up on the ratio between the amplitudes of the reference signal and the carrier signal which is termed as modulation index and the output frequency can be varied by varying the frequency of the reference signal. By using higher switching frequencies, harmonics can be shifted to higher orders.

2. Analysis

Operation of SPMC in AC-AC mode with variable output frequency, DC-AC mode with regenerative capability and DC-DC mode as a four quadrant chopper are analyzed.

2.1. SPMC as an AC-AC converter with variable output frequency

Table 1 :AC-AC Converter with variable frequency

Input Frequency	Output frequency	Mode	PWM Switch	Commutation Switch
50HZ	50HZ	1	S4	S1&S2’
		2	S1’	S3&S4’
	100HZ	1	S4	S1&S2’
		2	S3	S1&S2’
		3	S2’	S1’&S2
		4	S1’	S3&S4’
	25HZ	1	S4	S1&S2’
		2	S2’	S3’&S4
		3	S3	S1’&S2
		4	S1’	S3&S4’

When matrix converter is used as an AC-AC converter where both input and output frequencies are 50HZ, it has two modes of operation. Mode 1 for positive half cycle of input voltage and mode 2 for negative half cycle. The switches used during each mode are given in the table above. When SPMC works as a cycloconverter with step up in frequency(50 to 100HZ) and with step down in frequency (50 to 25HZ), usage of switches for each mode is also given in the table. For 50 to 100HZ conversion, the switching pattern is so as to split the 50HZ waveform into four inorder that the frequency will result in 100HZ.

2.2. SPMC as DC-AC Converter.

By simply varying the redundant switches, SPMC can work as a DC-AC converter. Due to its inherent regenerative capabilities, SPMC inverter can serve as a rectifier by simply interchanging the positions of source and load with small changes in the switching combinations.

Conventional inverters and rectifiers cannot claim the capability of regeneration and on the other hand SPMC is maintaining a better RMS output voltage compared to them.

Table 2. SPMC as DC-AC converter

	Switching combination		
	Mode	***Pwm switch***	***Commutation switch***
Inverter	1	S1	S4&S3’
	2	S2	S3&S4’
Rectifier	1	S4	S1&S2’
	2	S1’	S3&S4’

2.3. SPMC as DC-DC Chopper.

Table 4. SPMC as DC-DC chopper

itch	Switch position			
	First quadrant	***Second quadrant***	***Third quadrant***	***Fourth quadrant***
S1	pwm	open	open	open
S1’	open	closed	open	open
S2	open	open	pwm	open
S2’	open	open	open	closed
S3	open	pwm	close	open
S3’	closed	open	open	closed
S4	closed	open	open	pwm
S4’	open	closed	closed	closed

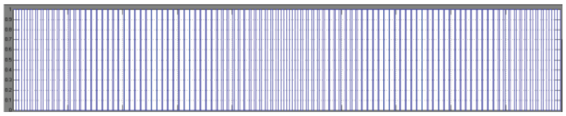
SPMC when works as a DC-DC chopper will operate in all the four quadrants and the switch positions will be as shown in Table 3.

3. Simulation Results

SPMC working in the above mentioned modes are simulated using Matlab-Simulink for the specifications given in table 4, and the obtained waveforms are given in Fig. 2 to Fig. 10. Table 5 gives the rms output voltages for the frequency changer mode of single phase matrix converter.

Table 4. Simulation parameters.

load	50 ohms
Input voltage	100V peak
Input frequency	50HZ
Output frequency	50HZ,100HZ,25HZ
Switching frequency	5kHZ
Modulation index	0.8



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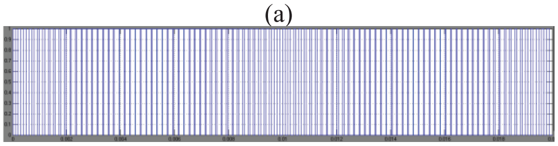
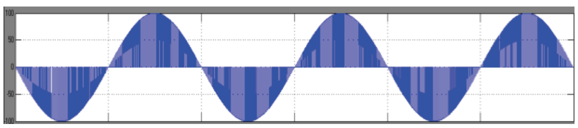


(b)

Fig 2. gate pulses (a) with positive SPWM (b) negative SPWM

3.1. SPMC as AC-AC converter with variable output frequency



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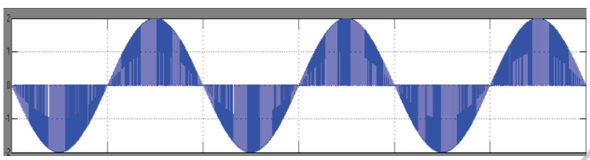

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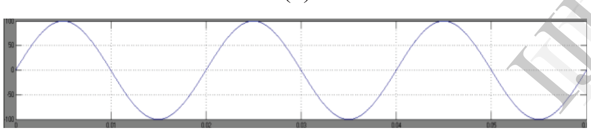
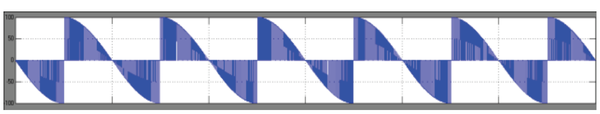


(c)

Fig 3. (a)Output voltage (b) Output current (c) Input voltage of SPMC in AC-AC conversion mode for 50HZ



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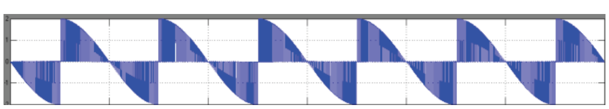

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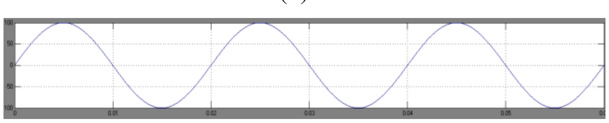

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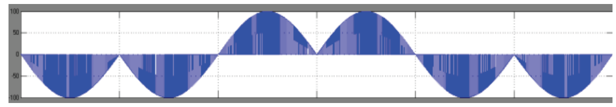
Fig 4. (a)Output voltage (b) Output current (c) Input voltage of SPMC in AC-AC conversion mode for 50HZ to 100HZ.



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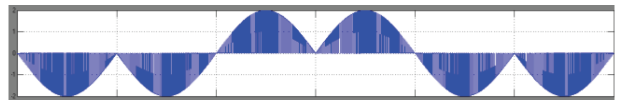

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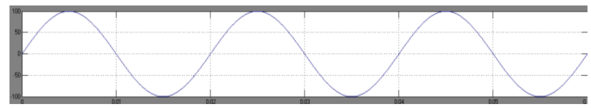


(b)

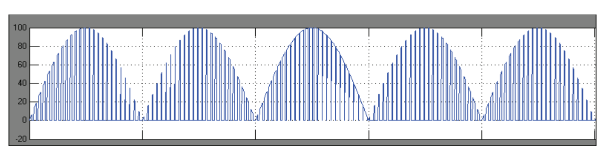
Fig 5. (a)Output voltage (b) Output current (c) Input voltage of SPMC in AC-AC conversion mode for 50HZ to 25HZ.

Table 5. Output voltage of SPMC working as frequency changer

Frequency	Rms output voltage *(volts)*
50-50HZ	68.62
50-100HZ	54.23
50-25HZ	50.98

3.2. SPMC as DC-AC converter with regenerative capability

Since SPMC has inherent regenerative capability by simply inter changing the source and load positions of an inverter it is possible to make it works as a rectifier. Changes have to be made only in the switching states as mentioned in Table 2. While comparing the performance of SPMC inverter and conventional inverter, it can be found that the RMS output voltage and THD of both are of comparable magnitudes, at the same time SPMC inverter has the advantage of regenerative capability due to the inherent bidirectional nature.



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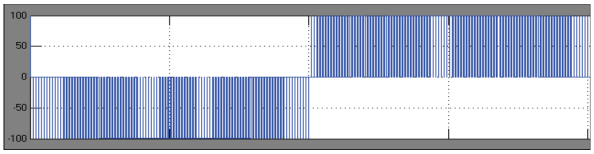

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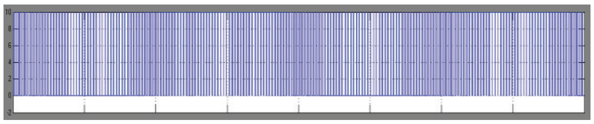
Fig 6. Output voltage of (a) Rectifier and (b) Inverter

3.3. SPMC as DC-DC four quadrant choppert



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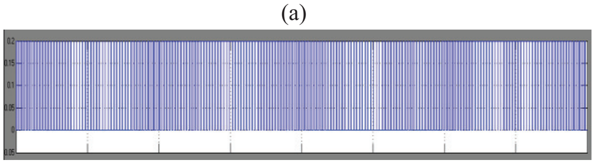

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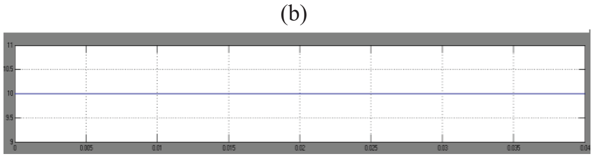

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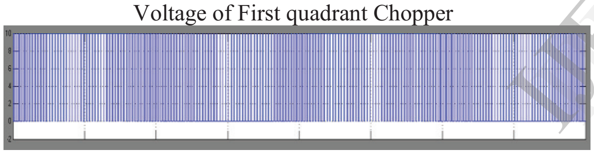
Fig 7. (a) Output voltage (b) Output current and Input Voltage of First quadrant Chopper



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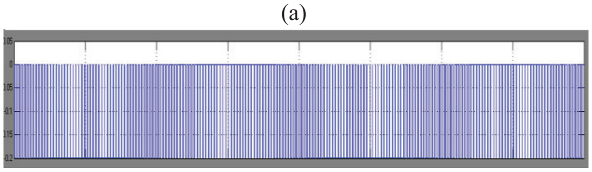
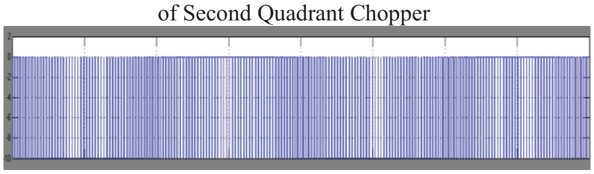


(b)

Fig 8 . (a) Output voltage and (b) Output current waveforms of Second Quadrant Chopper



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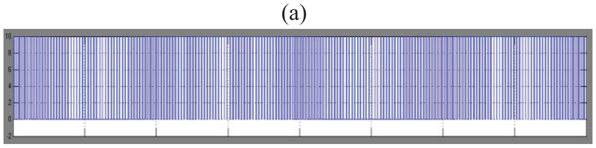
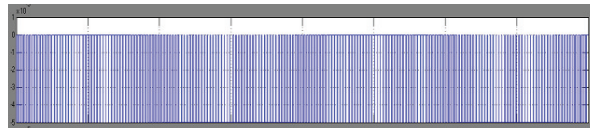


(b)

Fig 9. (a) Output Voltage and (b) Output Current waveforms of Third Quadrant Chopper.



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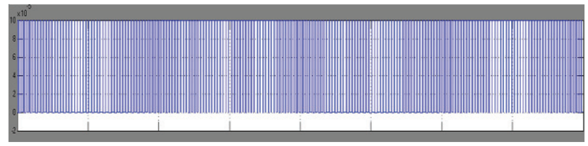

(b)

Fig 10. (a) Output Voltage and (b) Output Current Waveforms of Fourth Quadrant Chopper.

4. Conclusion

It is observed that SPMC gives flexible and versatile conversion with all sorts of power conversion topologies explained in this paper, however similar to any other nonlinear power electronic circuitry the total harmonic distortion can be considerably high. But it can be reduced to substantially acceptable margin with the use of single stage filter, THD can be reduced below 4%[2]. Also it can also be observed that SPMC does not require a DC link. Therefore by using SPMC, it is possible to reduce the size of the converter and to improve its life time.

5. References

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