International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 1, January - 2014

Design and Implementation of Single Phase Matrix Converter for Cycloconverter Operation

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Abstract

This paper presents the existing Single Phase Matrix Converter (SPMC) topology for direct conversion of AC-AC with step down frequency operation. The circuit composed from four ideal switches is used as a step down converter. The well known sinusoidal Pulse Width Modulation (SPWM) scheme is used to synthesize the output. Computer based simulation using MATLAB/SIMULINK and real time implementation using microcontroller validate its originality.

Key words: *Single phase matrix converter (SPMC), AC-AC conversion, Ideal switches, Sinusoidal Pulse Width Modulation (SPWM), Microcontroller.*

1. Introduction

Matrix converter is an advanced topology for direct AC-AC conversion. The circuit is arranged in such a way that any output lines of the converter can be connected to any input lines. The block diagram for proposed system is shown in Figure 1.

Figure 1. Block diagram of Matrix Converter

In this work, the SPMC is proposed for use in frequency reduction operation. The micro controller is used to produce the SPWM switching with IGBTs as the SPMC power switching device. Prior to hardware implementations, simulations were performed to predict the behavior. A laboratory model of the SPMC was then constructed to perform investigation. Objective of this project is to simulate the practical matrix converter with low frequencies. Results of the simulation and hardware are presented to verify the feasibility of proposed technique.

2. Single Phase Matrix Converter

This topology consists of a matrix of input and output lines with four bi-directional switches connecting the supply input to load at the intersections as shown in Figure 2. The SPMC comprises four bidirectional switches S1 to S4 'a' or 'b' where 'a' or 'b' is current flow directions ('a'- forward direction, 'b'- opposite direction) of each switch.

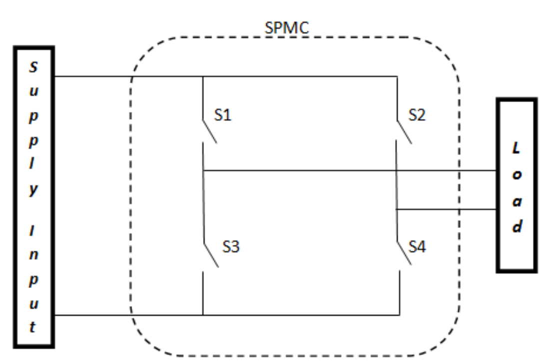


Figure 2. Circuit configuration

Each of the individual switches is capable of conducting current in both directions while at the same time capable of blocking voltage. In the absence of bidirectional switch module, the common emitter anti parallel IGBT with diode pair as shown in Figure 3 is used. The diodes provide reverse blocking capability to the switch module. The IGBT was used for its high switching capabilities and high current carrying capacities which are desirable for high power applications.

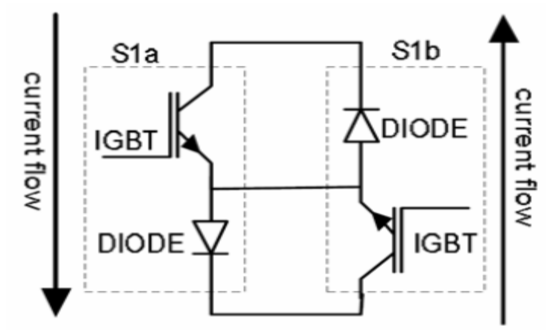


Figure 3. Bidirectional switch

The switching angle of the 4 bidirectional switches S1 to S4 'a' or 'b' represent the driver one and two respectively according to the following rules:

At any time 't', any two switches bellow will be ON:

- S1a and S4a will conduct the current flow during positive cycle of the input supply. (state1)
- S1b and S4b will conduct the current flow during negative cycle of the input supply. (state2)
- S2b and S3b will conduct the current flow during positive cycle of the input supply. (state3)
- S2a and S3a will conduct the current flow during negative cycle of the input supply. (state4) Figures 4 to 7 illustrate the same:

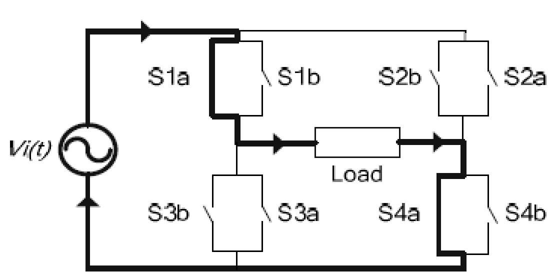


Figure 4. State 1 (Positive Cycle)

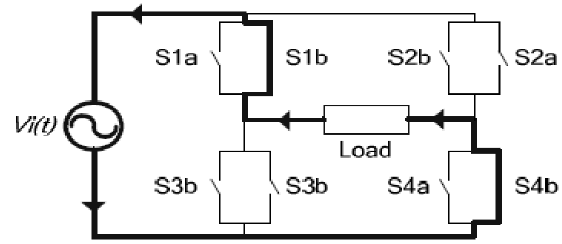


Figure 5. State 2 (Negative Cycle)

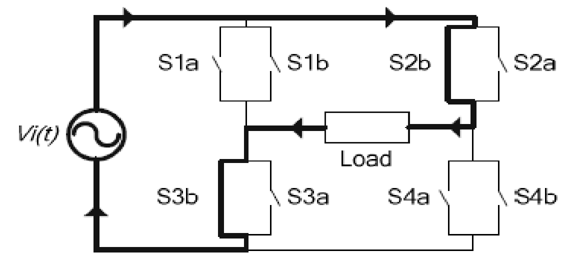


Figure 6. State 3 (Positive Cycle)

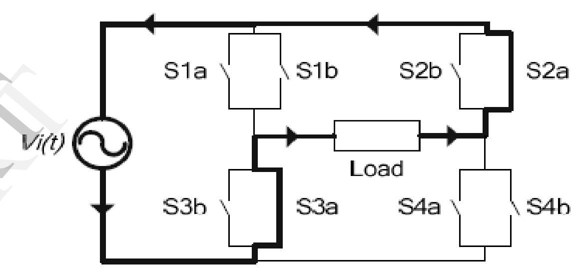
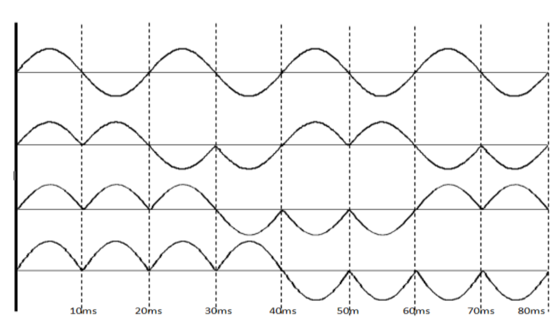


Figure 7. State 4 (Negative Cycle)

Implementation of SPMC with low frequency operation requires different bidirectional switching arrangements depending on the desired output frequency. For the present process the desired output frequency synthesized at half, onethird and onefourth of the input frequency as represented in Figure 8.



Fugure 8. Input frequency 50Hz, Output frequency 25Hz, 16.67Hz, 12.5Hz.

The switching sequences are dependent on the state of the driver circuit can be observed from Table-1 (for one cycle):

Input Frequency	Target Output Frequency	Time Interval	State	Switch "modulated"
50Hz	25Hz	1	1	S1a & S4a
		2	4	S3a & S2a
		3	3	S2b & S3b
		4	2	S4b & S1b
	16.67Hz	1	1	S1a & S4a
		2	4	S3a & S2a
		3	1	S1a & S4a
		4	2	S4b & S1b
		5	3	S2b & S3b
		6	2	S4b & S1b
	12.5Hz	1	1	S1a & S4a
		2	4	S3a & S2a
		3	1	S1a & S4a
		4	4	S3a & S2a
		5	3	S2b & S3b
		6	2	S4b & S1b
		7	3	S2b & S3b
		8	2	S4b & S1b

Table-1. Sequence of Switching Control

3. Sinusoidal Pulse Width Modulation

The well known SPWM used in power electronics is illustrated in Figure 9. For realisation a high frequency triangular carrier signal(V_c), is compared with a sinusoidal reference signal(V_{ref}) of the desired frequency. The cross over points are used to determine the switching instants.

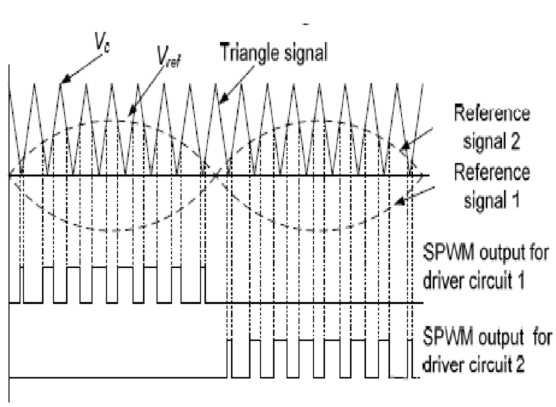


Figure 9. SPWM

The magnitude ratio of the reference signal(V_{ref}) to that of the carrier signal(V_c) is known as the *modulation index(m_i).* The magnitudeof fundamental component of output voltage is proportional to m_i. The amplitude V_c of the triangular signal is generally kept constant. However, varying the modulation index, the output voltage can be controlled.

4. Simulation

The proposed control concept is verified through simulation using MATLAB/SIMULINK as shown in Figure 10. Sim Power System Block set(PSB) in MATLAB/SIMULINK is used to model and simulate the circuit.

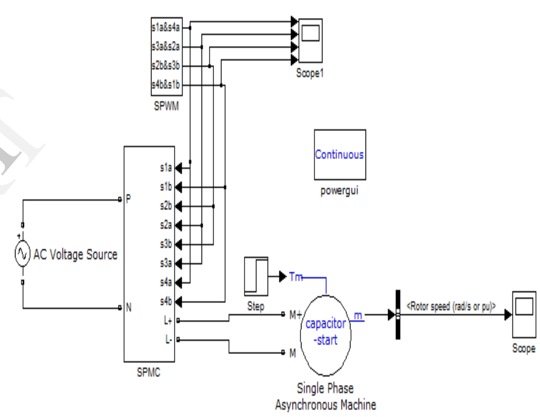


Figure 10. SIMULINK model of SPMC

Further Figures 10(a) & 10(b) present simulink model of the sub-blocks related to SPMC and SPWM, respectively.

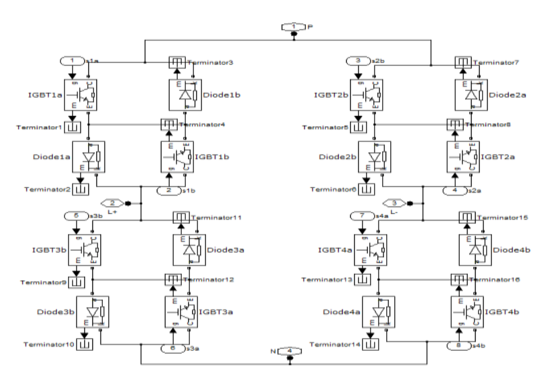


Figure 10(a). Sub block of SPMC

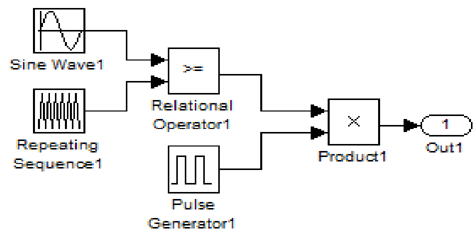


Figure 10(b). Sub block of SPWM

The carrier frequency(f_c) determines the number of pulses per half cycle. By varying the modulation index(m_i), the output voltage can be controlled.

The ripples present in the output of open loop SPMC can be reduced by connecting an PI controller. For this the speed of the open loop SPMC can be compared with the reference speed and the error signal given to the PI controller to generate the current wave form to control the switching pulses of the SPMC. The SIMULINK depiction of the closed loop circuit is presented in Figure 11.

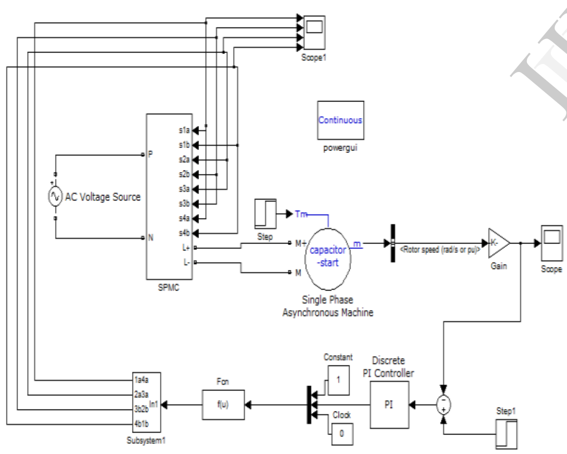


Figure 11. Closed loop circuit of SPMC

The switching sequence suggested in Table-1 gives the operation of the SPMC for low frequencies. (Simulation results of SPMC for different frequencies are given in Figures 14 to 19.)

5. Hardware

A Block diagram of Hardware model of the SPMC is shown in Figure 12. It consists of Zero Crossing Detector (ZCD), control unit, driver circuit, and the SPMC converter circuit.

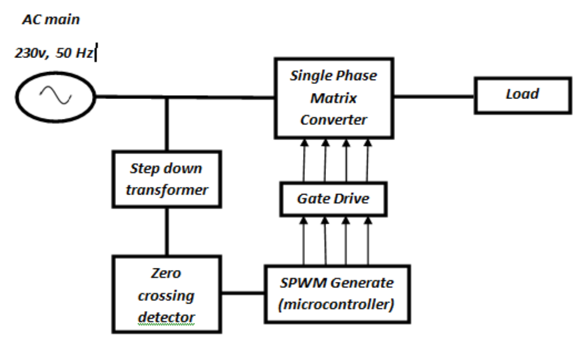


Figure 12. Block diagram of Hardware implementation.

The ZCD provide to detect the zero crossing point of the input voltage and conveys the same to control circuit. The control unit is used to determine the required driver permitted to produce gating pulse determined by the microcontroller. The output signal of the control unit is transformed to gating level by the use of driver circuits that are connected to the gate of switching devices in the SPMC circuit. The driver circuit also acts as an isolation device for the control unit to prevent voltage surges from damaging it.

(Figures 20 to 22 furnish the output results of the hardware implementation of SPMC for different frequencies.)

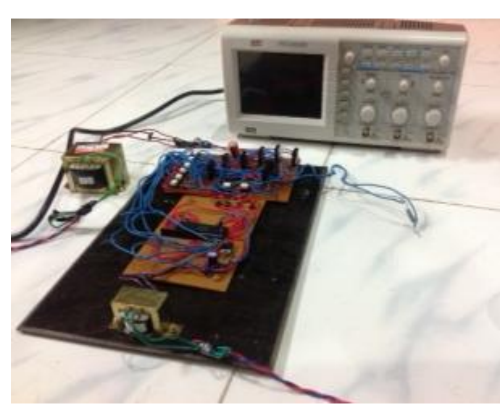


Figure 14. Hardware setup of SPMC

6. Results

The outputs derived from simulation method related to SPMC for different frequencies and the motor speed at 25Hz for Open loop and Closed loop is presented below.

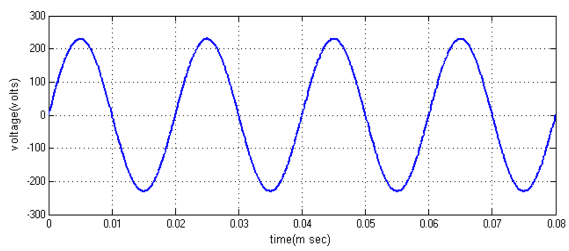


Figure 14. Input supply of 50Hz frequency to SPMC

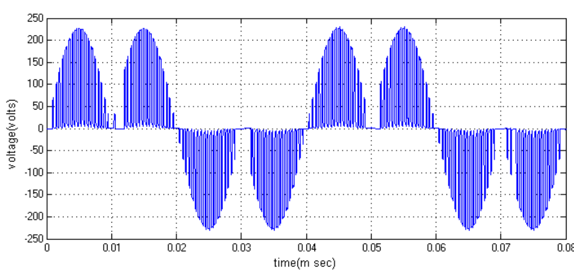


Figure 15. Output Voltage of SPMC at 25Hz

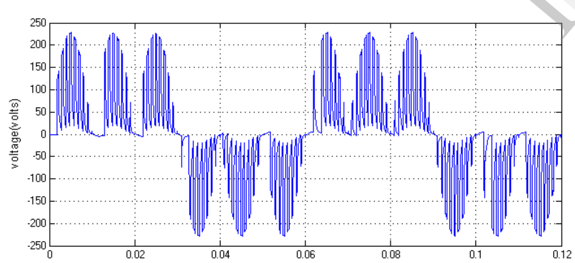


Figure 16. Output Voltage of SPMC at 16.67Hz

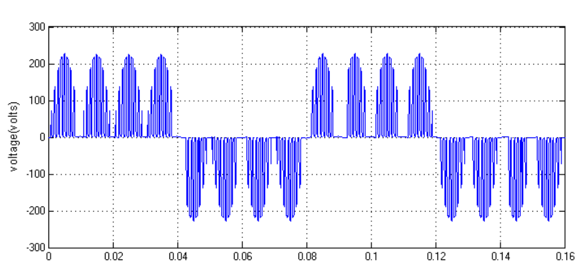


Figure 17. Output Voltage of SPMC at 12.5Hz

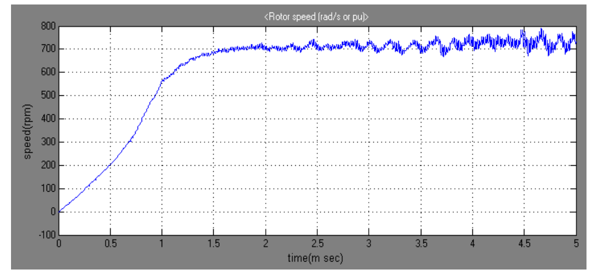


Figure 18. Speed of the Single Phase Induction Motor at 25Hz(open loop)

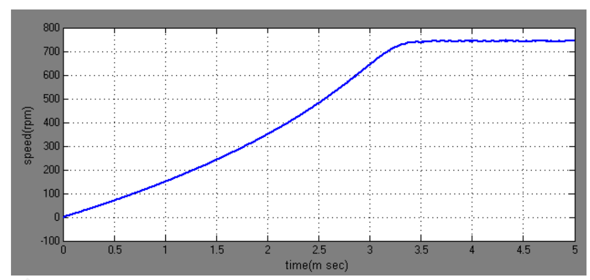


Figure 19. Speed of the Induction Motor at 25Hz(closed loop)

While executing the deviced hardware for this purpose are presented below.(The common load for all frequencies R=10KΩ.)

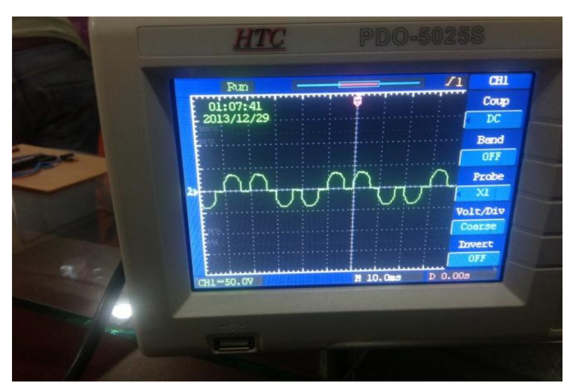


Figure 21. Output Voltage of SMPC at 25Hz frequency for R=10k ohm.

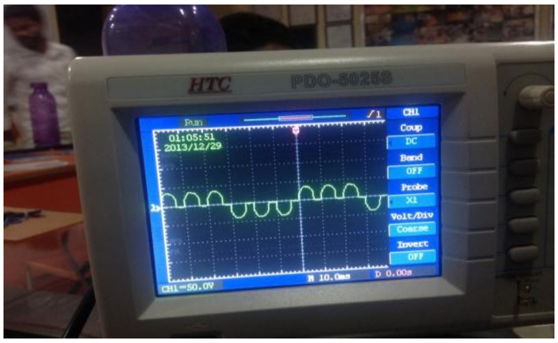


Figure 22. Output Voltage of SMPC at 16.67Hz.

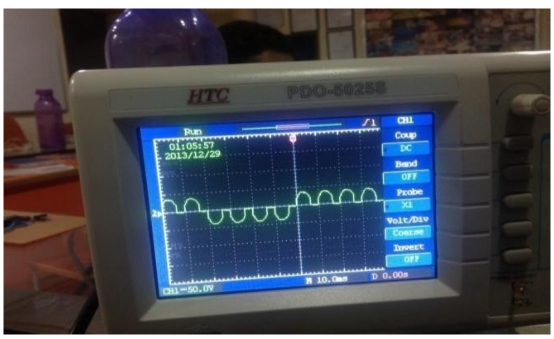


Figure-23. Output Voltage of SMPC at 12.5Hz.

Conclusion

The present project illustrates that the frequency of input supply can be changed with the help of Single Phase Matrix Converter having bidirectional switches. It is further revealed that the results obtained in simulation mode are in complaince with those derived through experimental(Hardware mode)

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Biography

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