

# Implementation of Single Phase to Single Phase Matrix Converter

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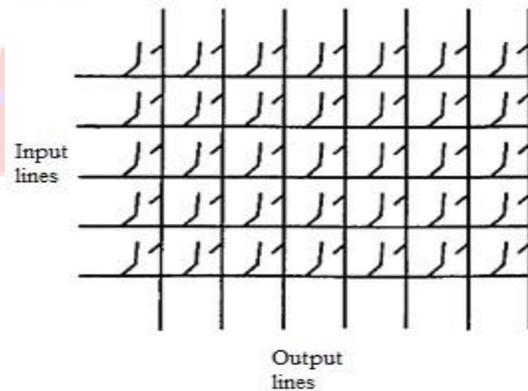
## ABSTRACT

Matrix converter is single stage converter which converts AC input power to variable voltage and frequency output AC power without using DC-link capacitor. As DC-link capacitor is eliminated the size of converter is reduced. Matrix converter uses number of controlled bidirectional switches to create variable voltage and variable frequency output power. In this paper the working principle of AC-AC Matrix converter is analyzed. The topology with required switching strategy is than modeled in MATLAB/SIMULINK, hardware implementation is done for verification of results and conclusion gained is presented.

**Keywords** — AC-AC converter, matrix converter, MATLAB simulation, power electronics

- Sinusoidal input and output wave forms with less higher order harmonics and no sub-harmonics.
- Bidirectional energy flow capability.
- Minimal energy storage requirements (minimal size reactive component)
- A controllable power factor.
- Operations in all four quadrants of the torque-speed plane due to the regenerative capability.
- High reliability and long life due to the absence of bulky electrolytic capacitors.
- Smaller and lighter design than other regeneration inverter with equivalent power ratings.

In matrix converter an arbitrary number of input lines can be connected to an arbitrary number of output lines directly using bidirectional semiconductor switches, as shown in Fig



1.[3]

Fig 1: General M-phase to N-phase matrix converter

## I. INTRODUCTION

AC-AC converters are commonly classified as direct converters and indirect converters. In Indirect converter conversion takes place in two stages AC-DC-AC. In this type of converter an energy storage element is use which can be either a capacitor or an inductor. However, in direct converter there is no energy storage device used. Direct converters can be classified into three topologies namely ac voltage controller, cycloconverter and matrix converter. The ac voltage controller is the simplest topology it changes the amplitude of the input ac voltage by simply chopping symmetric notches out of the input waveform. The second topology is used if a lower output frequency is desired and approximates the desired output waveform is obtained by synthesizing the pieces of the input waveform. In Matrix converter there is no limit of the output frequency and amplitude so it is considered as most versatile converter, which replaces the multiple conversion stages by a single power conversion stage without any intermediate energy storage device [1].

The matrix converter has received considerable attention in recent years because of its appealing characteristic [2]. Matrix converter having many advantages over conventional converter such as:

This paper deals with the basic principal of single phase to single phase Matrix converter. The model of single phase matrix converter (SPMC) is simulated by using SIMULINK/Matlab and tries to analyze the output. It also discuss about the required switching strategy for the converter and commutation required.

## II. SINGLE PHASE MATRIX CONVERTER

The SPMC topology is first developed by Zuberberger [4]. It consists of a matrix of four bidirectional switches which connects single phase input to single phase output. The key elements in a matrix converter are the fully controlled four quadrant bidirectional switch, which allows high frequency operation [1].

The single phase matrix converter scheme is shown in Fig.2.  $V_{in}$  is input voltage and  $V_{out}$  is output voltage. As shown in figure it consist of four bidirectional switches S1-S4 “a” and “b” were “a” shows forward direction and “b” reverse direction of current of each switch.

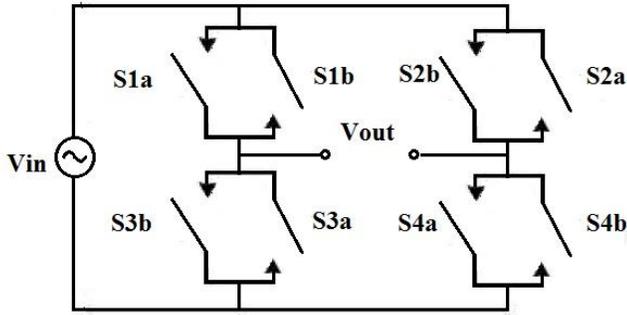


Fig.2: Single phase matrix converter scheme

### III. BIDIRECTIONAL SWITCHES

The matrix converter consists of bidirectional switches, which are capable of blocking voltage and conducting current in both directions. As there are no such devices currently available, Hence, discrete devices are used to construct suitable bi-directional switch and fulfill those requirements.

The diode bridge arrangement consists of an insulated gate bipolar transistor (IGBT) at the center of a single-phase diode bridge arrangement as shown in Fig.3. The main advantage is that both current directions are carried by the same switching device, therefore, only one gate driver is required per switch but the disadvantage that device losses are relatively high since there are three devices in each conduction path.

If the switching devices have a reverse voltage blocking capability then it is possible to build the bi-directional switches by simply placing two devices in anti-parallel as shown in Fig.3 (b). This arrangement can leads to a very compact converter with improved efficiency. However, reverse blocking IGBTs have shown poor reverse recovery characteristics which decrease the efficiency by increasing the switching losses.

The common emitter arrangement consists of two diodes and two IGBTs connected in anti-parallel as shown in Fig. 4(a). The diodes are included to provide the reverse blocking capability. There are several advantages in using this arrangement when compared to diode bridge arrangement. The first is that it is possible to independently

control the direction of the current. Conduction losses are reduced since there are only two devices are conducting at one time. One possible disadvantage is that each bidirectional switch cell requires an isolated power supply for the gate drives.

The common collector arrangement is shown in Fig. 4(b). In this type of arrangement conduction losses are the same as for the common emitter configuration. The disadvantage of this type of arrangement is the need of two isolated power supplies for the two gate drivers of the IGBT's [5]-[7].

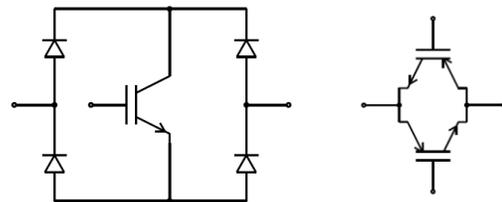


Fig.3: (a) Diode Bridge bidirectional switch (b) reverse blocking IGBT's

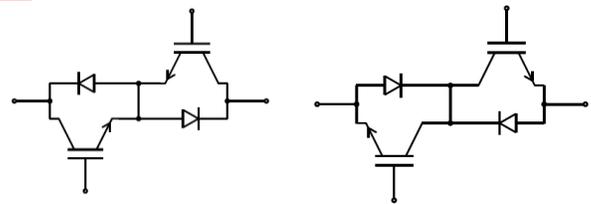


Fig.4: (a) Common emitter arrangement (b) Common collector arrangement

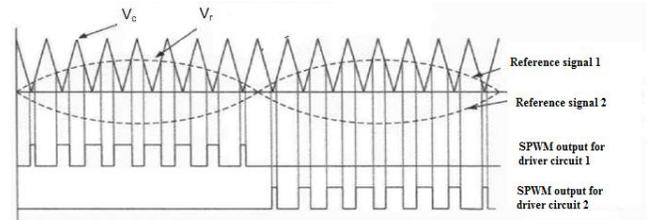


Fig. 5: SPWM formation

### IV. MODULATION TECHNIQUES

The Sinusoidal Pulse Width Modulation (SPWM) is a well known wave shaping technique in power electronics as illustrated in Fig. 4. In this techniques, a triangular wave carrier signal of high frequency,  $V_c$ , is compared with a sinusoidal reference signal,  $V_r$ , of the desired frequency.

The crossover points of both the signals are used to determine the switching instants. The modulation index (mi) will be the magnitude ratio of the reference signal ( $V_r$ ) to that of the carrier signal ( $V_c$ ). The magnitude of fundamental component of output voltage is proportional to mi. The

amplitude  $V_c$  of the triangular signal is generally kept constant. By varying the modulation index, the output voltage could be controlled [8].

The commutation problem is an important issue to be considered in for matrix converter. As there is absence of dc link capacitor so there is very strong coupling between input and output. The switching must be instantaneous and simultaneous so that there should not be open circuit of load and short circuit of source should be taken places. Else there will be generation of over current or overvoltage spikes that can in turn destroy power semiconductor devices. At any time during switch turn 'OFF' there should be a path for inductive load current to flow to prevent large overvoltage that would destroy switches [9][10].

### V. SWITCHING STRATEGY

It changes AC voltage amplitude and frequency without DC link and additional bulky passive components. Control system is designed to generate the sine pulse wide modulation SPWM patterns that are used to control the power switches. The switching angles, of the 4 bi-directional switches  $S_{ij}$  ( $i = 1,2,3,4$  and  $j = a, b$  which are presented in previous section). The following rules are then applied;

State 1 (Positive cycle): At any time 't', only two switches  $S_{1a}$  and  $S_{4a}$  will be in 'ON' state and conduct the current flow ,when  $S_{4a}$  will be off  $S_{2a}$  turn 'ON' for commutation purpose as shown in Fig.6

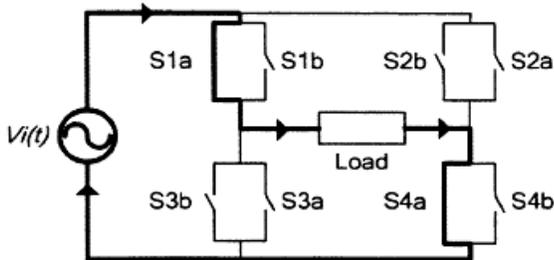


Fig. 6: Switching State 1

State 2 (Negative cycle): At any time 't', only two switches  $S_{1b}$  and  $S_{4b}$  will be in 'ON' state and conduct the current flow in negative direction ,when  $S_{4b}$  will be off  $S_{2b}$  turn 'ON' for commutation purpose as shown in Fig 7

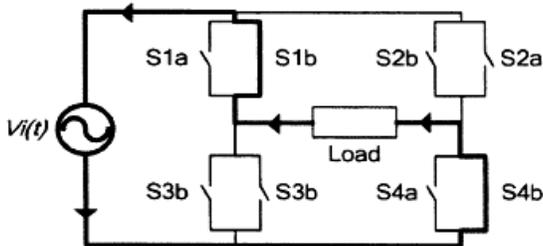


Fig. 7: Switching State 2

State 3 (Positive cycle): At any time 't', only two switches  $S_{2b}$  and  $S_{3b}$  will be in 'ON' state and conduct the current flow in negative direction ,when  $S_{3b}$  will be off  $S_{1b}$  turn 'ON' for commutation purpose as shown in Fig.8

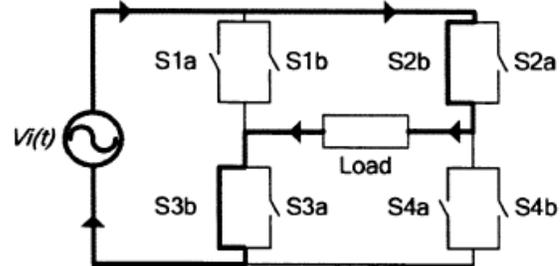


Fig.8: Switching State 3

State 4 (Negative cycle): At any time 't', only two switches  $S_{2a}$  and  $S_{3a}$  will be in 'ON' state and conduct the current flow in positive direction ,when  $S_{4b}$  will be off  $S_{1a}$  turn 'ON' for commutation purpose as shown in Fig.9

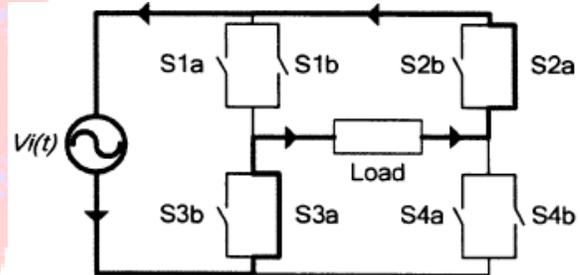


Fig.9: Switching State 4

Switching configuration for various output Frequency are mentioned in table no.1

Input Freq.	Output Freq.	Time Interval	State	PWM switch	Commutation switches
50	50	1	1	S4a	S1a & S2a
		2	2	S4b	S1b & S2b
	25	1	1	S4a	S1a & S2a
		2	4	S3a	S2a & S1a
		3	3	S3b	S2b & S1b
		4	2	S4b	S1b & S2b

Table1 Switching Configuration for Various Output Frequency

### VI. SIMULATED MODEL AND RESULTS

The Single Phase Matrix Converter modeled by using MATLAB/SIMULINK as shown in Fig. 10 the switching arrangement used is common emitter type as shown in Fig. 11.The SPWM technique is use for generation of pulses.

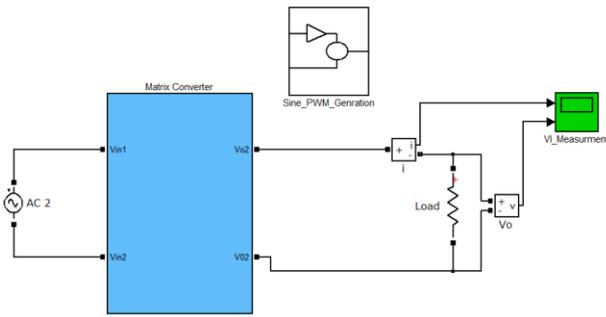


Fig.10: Simulation Model of Matrix Converter

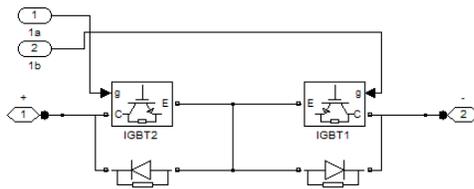


Fig.11: Switching arrangements

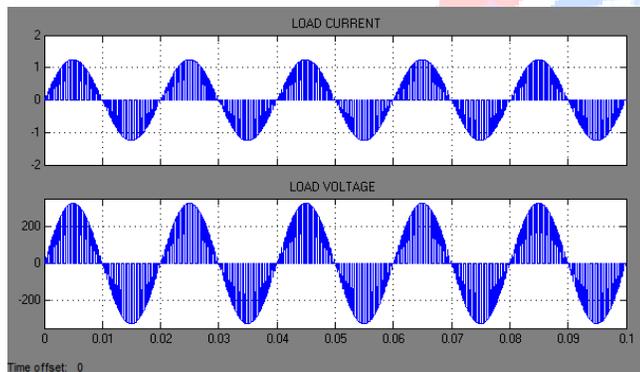


Fig. 12: Simulation results for R Load (50Hz)

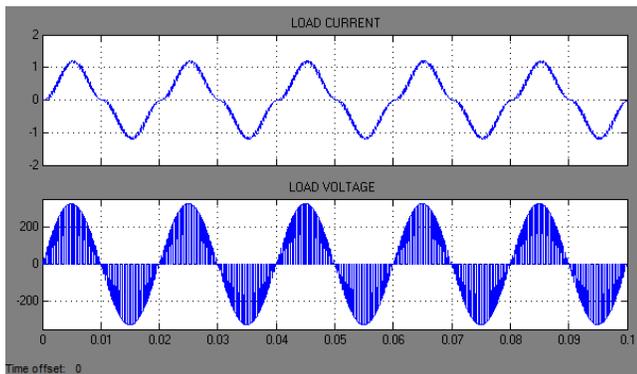


Fig. 13: Simulation results for R-L Load (50Hz)

Simulation results for 50 Hz Frequency are shown in Fig. 12 & Fig.13 Parameters used for SPMC simulation are mentioned in Table 2. The output current THD for R and R-L Load is given in Table 3.

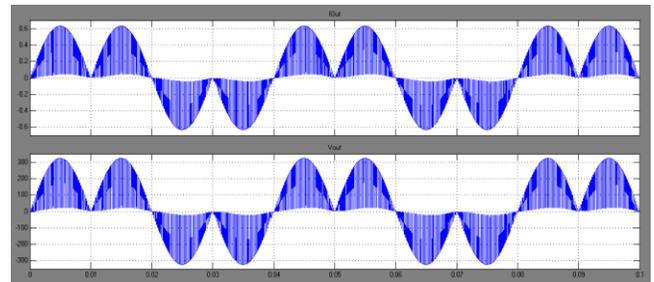


Fig.14: Simulation Result for R Load (25Hz)

Result for 25 Hz Frequency is shown in Fig. 14 & 15. Variation of Current harmonics with various switching is shown in Fig 16.

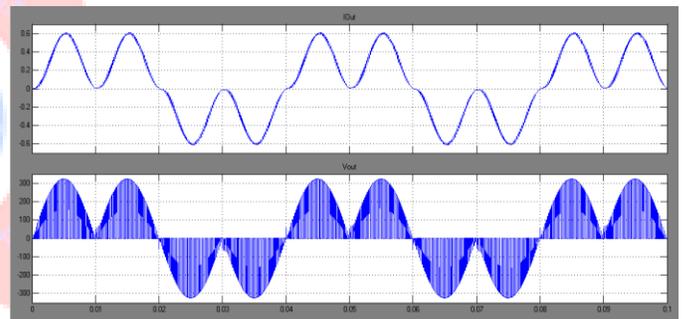


Fig.15: Simulation Result for R-L Load (25Hz)

Vin	230r.m.s
Input Frequency	50Hz
Switching Frequency	10 KHz
Modulation Index	0.9
PWM Techniques	Sine PWM
Load	50W

Table 2 Simulation Parameters

Load Type	$I_{THD}\%$
R load Without Filter	26.92
R-L Load Without Filter	19.42

Table 3 Output Current THD

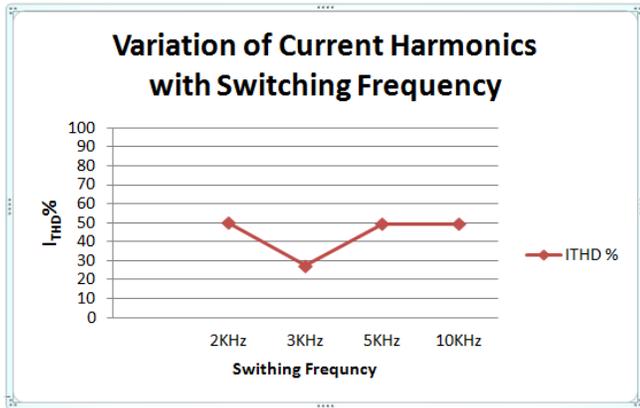


Fig. 16 Variation of Current Harmonics with switching frequency



Fig.19 Final Matrix converter setup

## VII. HARDWARE RESULTS

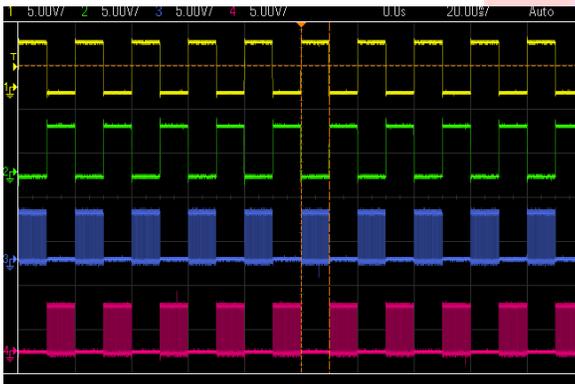


Fig. 17. PWM for various switches

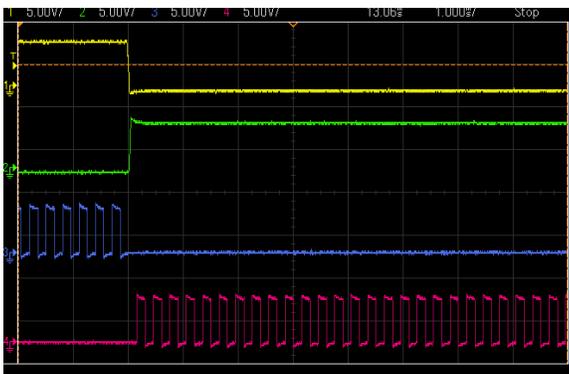


Fig. 18 Time delay for Commutation purpose

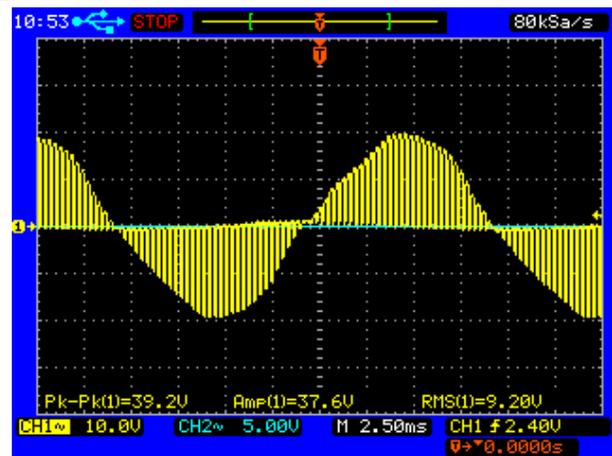
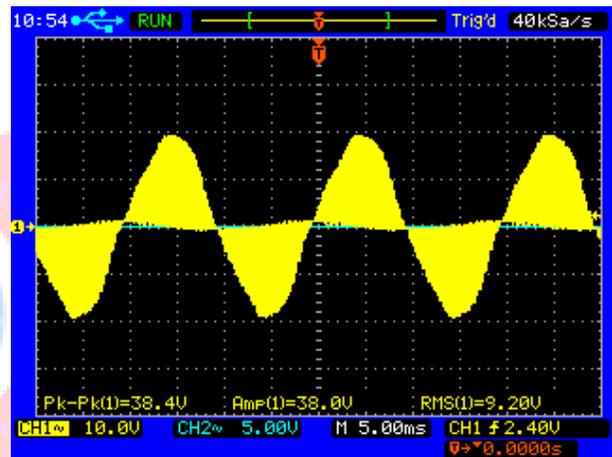


Fig. 20 output waveform of the single phase matrix converter

### VIII. CONCLUSION

In this paper the topology of single phase matrix converter is simulated in Matlab/Simulink and the results for various loads and various frequencies are provided. Hardware implementation is carried out for single phase to single phase matrix converter and results are verified and provided. SPWM technique is developed for switching and a safe commutation technique is implemented to avoid current spikes by allowing the dead time. Matrix converter technology has potential benefits especially for applications where size, weight, and long term reliability are the important factors. Having many advantages, MC has very limited applications due to non-availability of full controlled bi-directional switch and complex control system.

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