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Analysis Of Single Phase Matrix Converter

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ABSTRACT
This paper presents concept of single phase matrix converter. Single phase matrix converter (SPMC) performs a function such as frequency changer, rectifier, inverter; chopper. This reduces the need for new converter hardware. Pulse width modulation (SPWM) techniques are used to calculate the switch duty ratio to synthesis the output. The simulation of converter is carried out in MATLAB/SIMULINK. Hardware design is obtained using readily available IC's and other components. This paper discusses the new multiple converter for single phase input using matrix topology using just a single control logic.
Keywords - Chopper, Cyclo-converter, Inverter, Matrix converter, MATLAB/SIMULINK.

I. INTRODUCTION

Power electronic applications have become very common in modern commercial and industrial environments particularly in applications of AC-DC conversions. Traditionally ac and dc conversion systems are used separately for ac and dc loads. Currently no system is available to get AC and DC output simultaneously. Novel concept of multiple converter means that it can give AC and DC output simultaneously using single control circuit. For the implementation of such a multiple converter matrix topology is used. The Matrix Converter (MC) is an array of bidirectional switches as the main power elements, which interconnects directly the Input supply to the load, without using any dc-link or large energy storage elements.

The Matrix Converter (MC) is an advanced circuit topology that offers many advantages such as the ability to regenerate energy back to the utility, sinusoidal input and output current and a controllable input current displacement factor [1]. It has the potential of affording an "all silicon" solution for AC-AC conversion, removing the need for reactive energy storage components used in conventional rectifier-inverter based systems. The Single-phase matrix converter (SPMC) was first realized by Zuckerberger [2]. It has been shown that the SPMC could be used to operate as a direct AC-AC single-phase converter [3], DC chopper [4], rectifier [5] & inverter [6]. In this papera new multiple converters using matrix topology for allconversions using a single circuit is presented.

II. SINGLE PHASE MATRIX CONVERTER

A power electronic system consists of one or more power electronic converters. The switching characteristics of power semiconductor devices permit a power electronic converter to shape the input power of one form to output power of other form. Static power converters perform various power conversion very efficiently. Ac and dc conversion systems are used separately for ac and dc loads.

For different types of conversion different circuits are used. But in certain applications like uninterruptable power supply which converts AC into DC for charging the batteries using rectifiers and then converts the stored energy again into AC using inverter, requires two conversion circuits. Also in traction different types of motors are employed such as DC series, DC shunt and AC series which require conversion of supply. A number of conversion kits are required in laboratories. This increases the total cost and also the space requirement.

A recent technology known as single phase matrix converter is capable of performing all these conversions. The use of a matrix converter in the future reduces the need for learning many varying converter topologies and that is now the subject of current active research.

Fig. 1(a) shows a SPMC that requires four bi-directional switches capable of blocking voltage and conducting current in both directions. The common emitter anti-parallel IGBT, with diode pair is used in absence of bidirectional switch module as in fig. 1(b). The IGBT was used due to its high switching capabilities and high current carrying capacities.

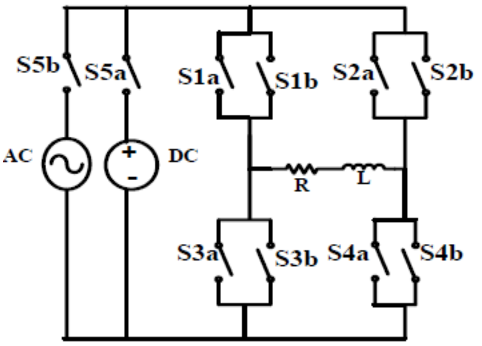


Fig. 1(a) Basic Circuit

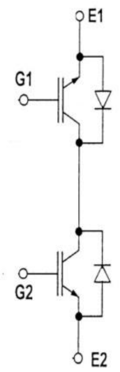


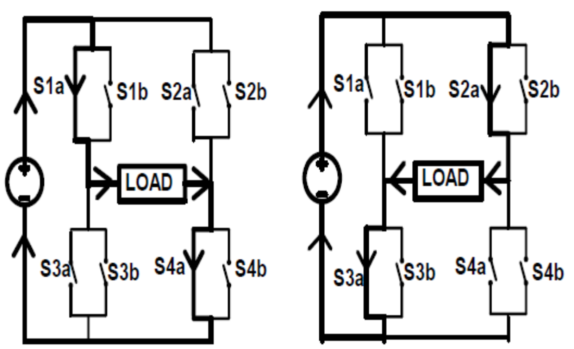
Fig. 1(b) Common Emitter Bidirectional Switch

The output can be synthesized by suitable toggling of the matrix switches subject to the conditions that ensures the switches do not short-circuit the voltage sources, and do not open-circuit the current sources.

The advantage of this approach is that it can be developed for any kind of input (AC or DC) and produces any output (AC or DC).

a. SPMC as Inverter

Inverter refers to the process of converting a DC voltage or current to AC voltage or current.



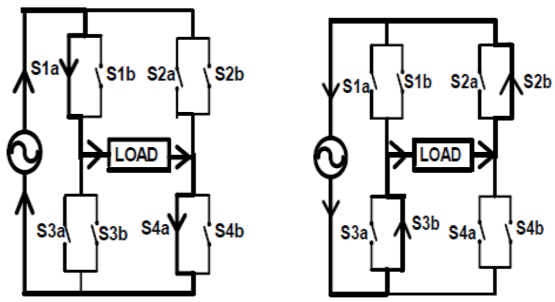
(a) For positive Output (b) For Negative Output

Fig. 2 Inverter operation

For an inverter operation, the input is DC for positive half output switches S1a and S4a will conduct while negative output switches S2a and S3a will conduct as shown in Fig. 2 (a) and (b) respectively.

b. SPMC as Rectifier

Rectifier refers to the process of converting an AC voltage or current to DC voltage or current.



Converter

Fig.3 Rectifier Operation

For a rectifier operation, the input is AC for positive half output switches S1a and S4a will conduct while negative output switches S3b and S2b will conduct as shown in Fig. 3.

c. SPMC as CHOPPER

Chopper refers to the process of converting a fixed DC voltage into variable DC voltage.

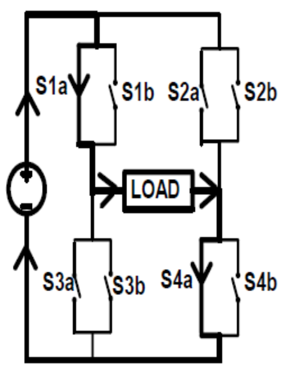


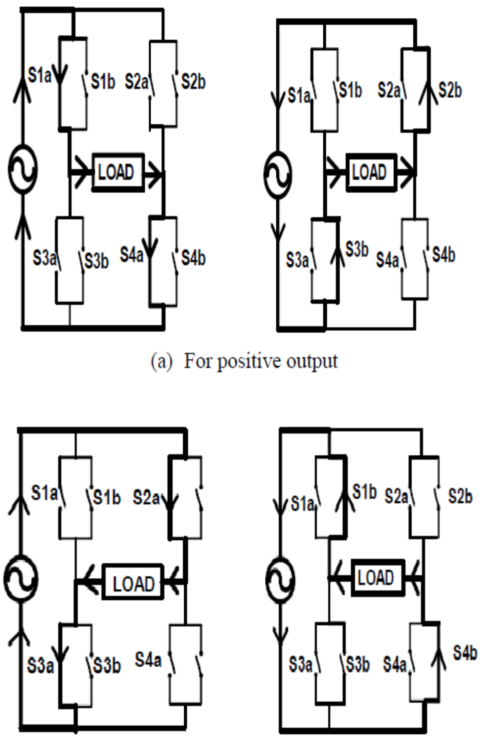
Fig. 4 Chopper Operations

For a chopper operation the input is DC, switches S1a and S4a will conduct as shown in Fig. 4.

d. SPMC as Cyclo-Converter

A device which converts input power at one frequency to output power at different frequency with one- stage conversion is called cyclo-converter.

If input is AC then there are four switching states that can be explained with the cyclo-converter operation. Fig. 5 shows the cyclo-converter operation for half of the input frequency. In the positive input cycle if the output is positive switches S1a and S4a will conduct while in the negative input cycle if the output is positive switches S3b and S2b will conduct. The negative half output of cyclo-converter is obtained by conduction of switches S2a and S3a and switches S4b and S1b as shown in Fig. 5 (a) and (b) respectively.



(a) For positive output

(b) For Negative output

Fig. 5 Cyclo-converter Operation

Following Table 1 summarize the different switching combinations for various operations of single phase matrix converter.

Table1 Switching Combination for Different converter Operation

Converter	Output signal (Conducting switches)
Inverter	S1a, S4b
	S2a, S3a
Rectifier	S1a, S4a
	S2b, S3b
Chopper(First Quadrant operation)	S1a, S4a
Cyclo Converter	S1a,S4a S2b,S3b
	S2a,S3a S1b,S4b

III. Sinusoidal Pulse Width Modulation

The switches in the voltage source inverter (See Fig. 6) can be turned on and off as required. In the simplest approach, the top switch is turned on and off only once in each cycle, a square waveform results. However, if turned on several times in a cycle an improved harmonic profile may be achieved.

Pulse width modulation (PWM) is a widely used technique for controlling the output of static power converters. PWM is immune to noise and less susceptible to voltage changes. The harmonic content can be reduced by using PWM pulses in each half cycle of output voltage.

In the most straightforward implementation, generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as depicted schematically in Fig.7. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output. Note that over the period of one triangle wave, the average voltage applied to the load is proportional to the amplitude of the signal (assumed constant) during this period. The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies of a close to the carrier frequency. Notice that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and hence the total harmonic distortion is not affected by the PWM process. The harmonic components are merely shifted into the higher frequency range and are automatically filtered due to inductances in the ac system.

When the modulating signal is a sinusoid of amplitude Am, and the amplitude of the triangular carrier is Ac, the ratio m=Am/Ac is known as the modulation index. Note that controlling the modulation index therefore controls the amplitude of the applied output voltage. With a sufficiently high carrier the high frequency components do not propagate significantly in the ac network (or load) due the presence of the inductive elements. However, a higher carrier frequency does result in a larger number of switching per cycle and hence in an increased power loss. Typically switching frequencies in the 2-15 kHz range are considered adequate for power systems applications.

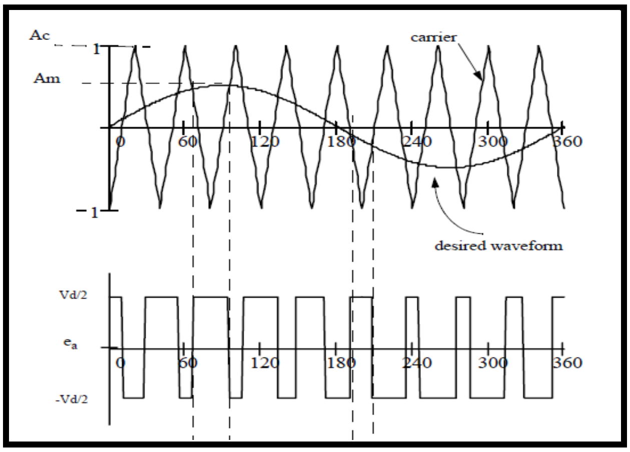


Fig. 6 SPWM

The process works well for m≤1. For m>1 there are periods of the triangle wave in which there is no intersection of the carrier and the signal as in Fig. 7. However, a certain amount of this "over modulation" is often allowed in the interest of obtaining a larger ac voltage magnitude even though the spectral content of the voltage is rendered somewhat poorer.

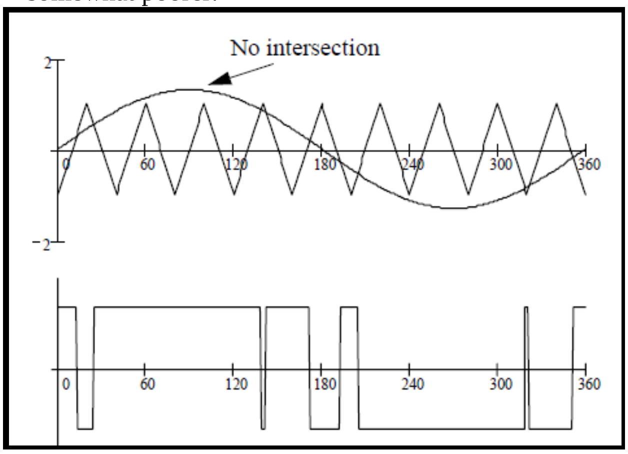


Fig.7 SPWM

IV. SIMULATION AND RESULT

Simulation is carried out in Matlab-Simulink for Input Voltage of 100 V, 50Hz with R Load and RL Load.SPWM Technique is used for Controlling Switches.

The scheme of the block diagram describing the matrix converter as inverter is shown in Fig.8 (a).

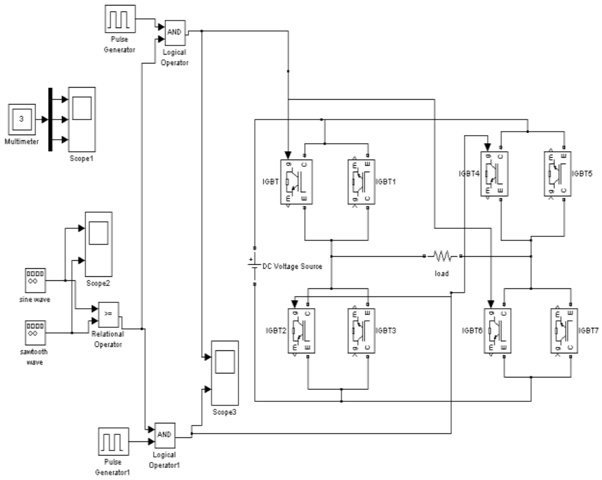


Fig.8(a) Simulation Model Of Inverter

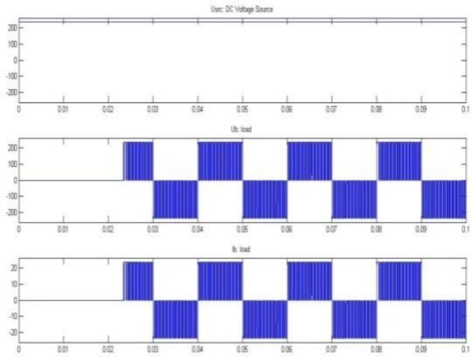


Fig. 8(b) Inverter Output

Fig.8 (b) shows the output voltage across the load and output current across the load for SPMC as inverter.

The scheme of the block diagram describing the matrix converter as rectifier is shown in Fig.9 (a).

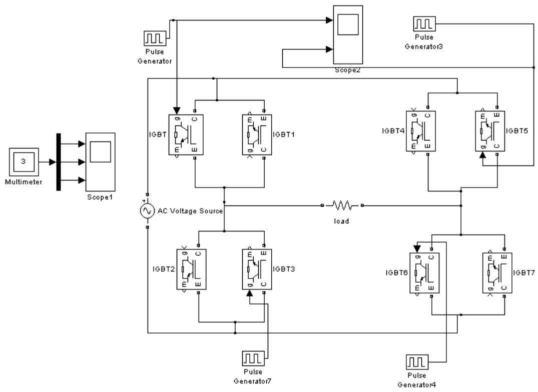


Fig. 9(a) Rectifier

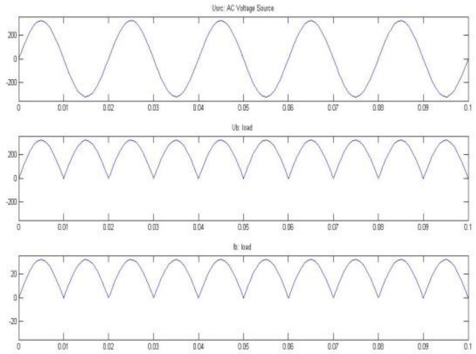


Fig. 9(b) Rectifier Output

Fig.9 (b) shows the output voltage across the load and output current across the load for SPMC as converter.

The scheme of the block diagram describing the matrix converter as chopper is shown in Fig.10 (a).

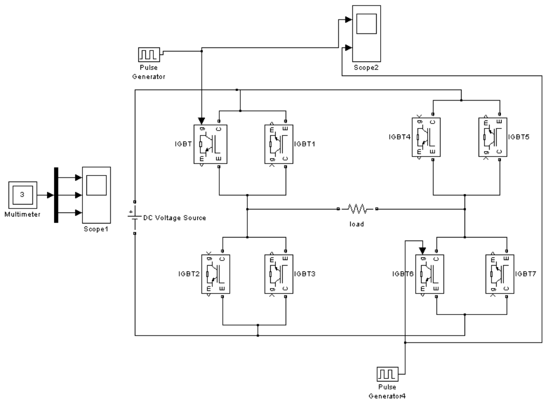


Fig.10 (a) Chopper

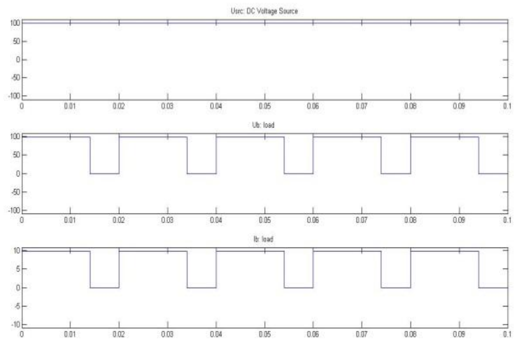


Fig. 10(b) Chopper output

Fig.10 (b) shows the output voltage across the load and output current across the load for SPMC as chopper.

The scheme of the block diagram describing the matrix converter as cycloconverter is shown in Fig.11 (a).

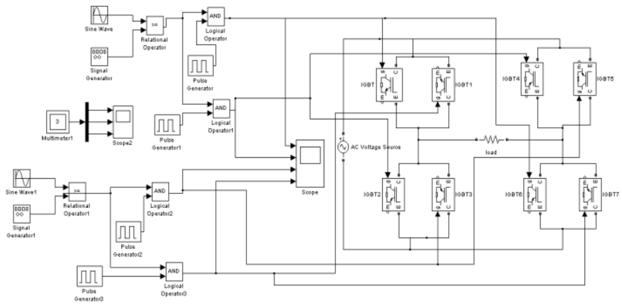


Fig.11 (a)Cycloconverter

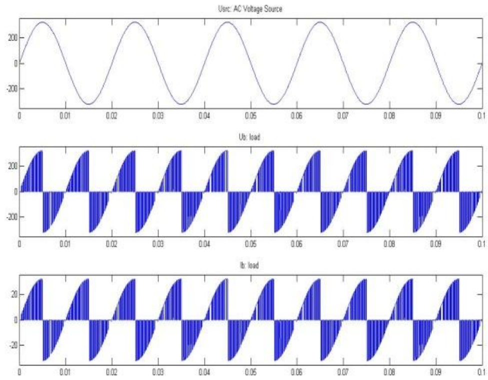


Fig.11 (b) Cycloconverter Output

Fig.11 (b) shows the output voltage across the load and output current across the load for SPMC as cycloconverter.

V. EXPERIMENTAL RESULTS

Experimental results are obtained by observing the waveforms on CRO.

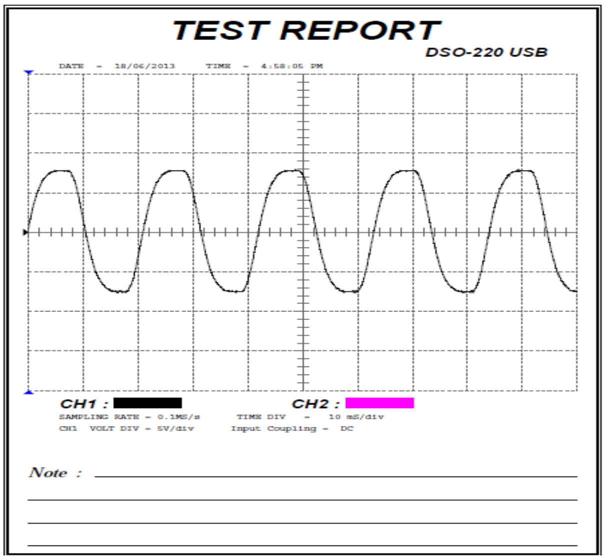


Fig. 12(a) Inverter Output

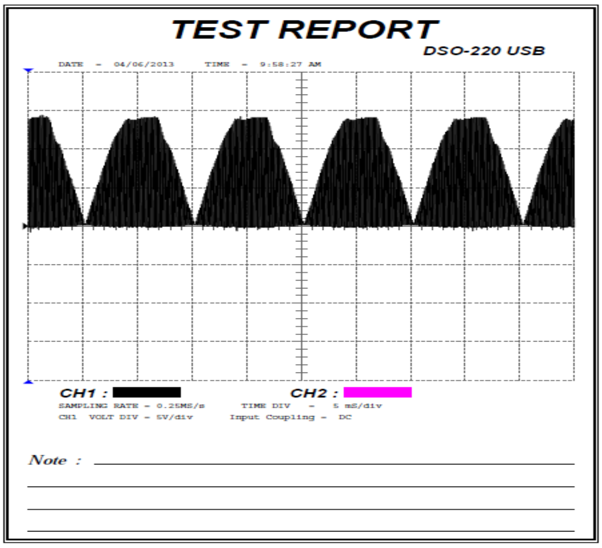


Fig. 12(b) Rectifier Output

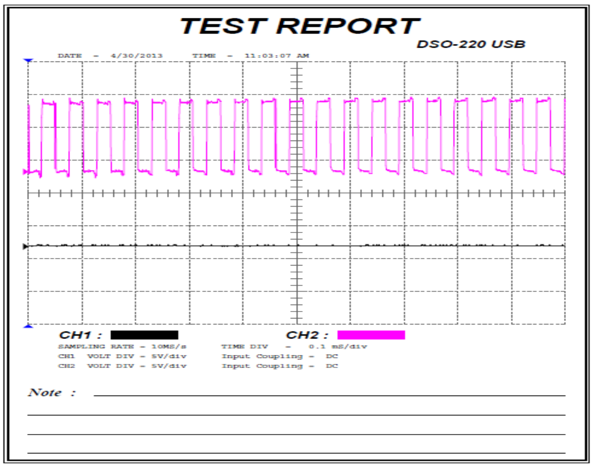


Fig. 12(c) Chopper Output

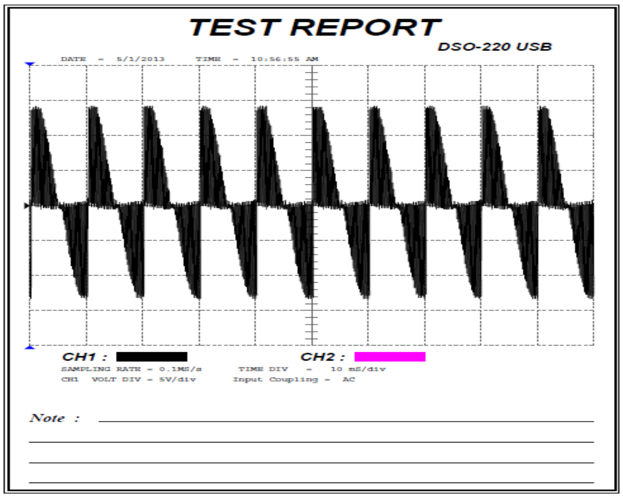


Fig. 12(d) Cycloconverter Output

VI. CONCLUSION

It has been outlined and illustrated that the single-phase matrix converter can be conceived designed and realized by suitable switching schemes, where IGBTs are used for the main power switching device. When fed from the mains at constant frequency and amplitude the converter is capable of synthesizing an output voltage with a fundamental equal to input frequency multipliers, so that the converter is a frequency step-up and voltage step-down converter. From results obtained it has been shown that the SPMC can have either AC or DC supply input and synthesized AC or DC output using a well-known PWM technique. The output waveform has been synthesized using Pulse Width Modulation.

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