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MULTIOPERATION OF SPWM BASED SINGLE PHASE MATRIX CONVERTER

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ABSTRACT

This paper presents the multi - operation of Sinusoidal Pulse Width Modulation (SPWM) based Single Phase Matrix Converter (SPMC). The matrix converter converts fixed AC/DC to variable AC/DC. Single converter replaces rectifier, AC voltage controller, inverter, frequency changer and chopper. Losses due to the dc link used in the inverter are eliminated as the SPMC is a single stage converter. This increases the efficiency of the converter. The output waveform of SPMC can be synthesized using the SPWM techniques which utilize AC or DC supply as the input. The anti-parallel connection of common emitter Integrated Gated Bi-Polar Transistor (IGBT) and diode is used as a bi-directional switch. Simulation studies have been carried out in MATLAB/Simulink and the results are presented.

Keywords: single phase matrix converter (SPMC), sinusoidal pulse width modulation (SPWM), integrated gated Bi-Polar transistor (IGBT).

1. INTRODUCTION

In recent decades the power electronic devices play very important roles in industrial applications. Traditionally different devices are employed to do DC and AC power conversion separately. But certain applications need both AC and DC power for its operation in such a case it will be more convenient if a single control circuit can perform both power conversion. To fulfill this requirement a new matrix converter topology is designed which carry out all the basic function of single phase power electronic converters.

The Matrix converter (MC) is the upcoming superior topology, which offers all types of power conversion [1]. The Matrix converter is become more attractive because of its advantages such as bi-directional flow of capability, reduction in energy storing devices, controllable I/O currents, and displacement factor [2]. Matrix Converter can be designed using array of controllable bidirectional switches which are arranged in a manner that any input phase can be connected to any output phase.

MC is a force commutated converter in which the proper arrangement of bidirectional switches is most important to obtain the desired output. Commutation is one of the major problems in three phase matrix converter. SPMC topology was first reported by Gyugyi and Pelly in 1976 [3]. Later this was developed by Venturini in 1980 [4]. Initially it is used for the purpose of AC-AC conversion only and so it having another name as PWM Cyclo-Converter. From 1980 onwards the three phase matrix converter became more popular. In a while the single phase matrix converter topology was realized by Zuckerberger and Weinstock in 1997 [5]. In 2001 Hossieni realized the inverter using this topology [6] and Firdaus the one who first introduced SPWM scheme in Single Phase Matrix Converter in 2002 [7].

Based on the review of many articles, it is shown that Single Phase matrix converter is capable to do any type of power transformation such as DC-DC (chopper) [8], AC-AC (AC voltage controller) [9], AC-DC (rectifier) [10], DC-AC (inverter) [11], AC power with fixed frequency to AC power with variable frequency (frequency changer). Earlier articles discuss one converter operation at a time for safe commutation purpose. In this paper the collective functions of all other traditional converters is replaced by a single circuit. For R load, the operation of SPMC as a rectifier, AC voltage controller, inverter, frequency changer is simulated. To achieve the performance of SPMC as four quadrants DC chopper RLE load has been used.

This paper presents the study of SPMC which performs the multiple functions similar to traditional converters in Section II. The simulations implementation and results is shown in Section III followed by conclusion in section IV.

2. SINGLE PHASE MATRIX CONVERTER

The SPMC is matrix of input and output lines with two legs of four bi-directional switches as shown in Figure-1.

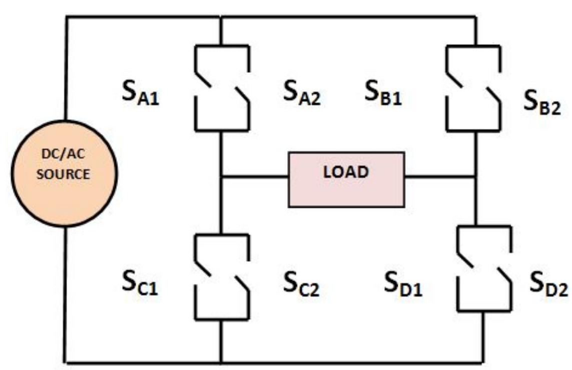

Figure-1. Power circuit of SPMC.

The anti-parallel connection of IGBT with diode shown in Figure-2. The IGBT is preferred for its high current carrying and fast switching capability. This configuration is capable of conducting current and

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blocking voltage in both directions. The advantage of this SPMC is capable of giving any type of power (AC or DC) as output for any input supply (AC or DC) depends on turning on/off the appropriate switches at proper time instant.

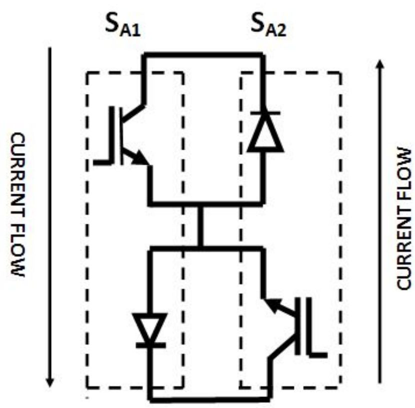

Figure-2. Common emitter IGBT configuration.

A. SPMC as Rectifier

Rectifier is a device which converts constant AC power into controlled DC power. In the SPMC such rectification is performed when the input source is AC. During first half cycle the switches S_{A1} and S_{D1} are turned on while in second half cycle the switches S_{C2} and S_{B2} are turned on shown in Figure-3.

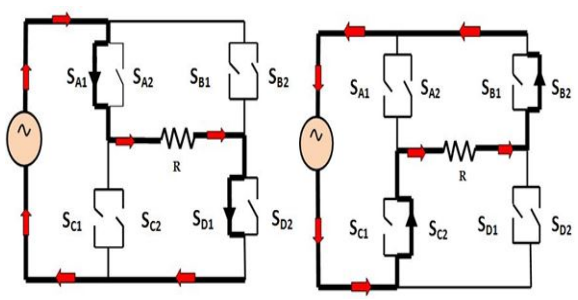

Figure-3. Modes of SPMC as Rectifier.

B. SPMC as Inverter

The DC power is converted into AC power by the device is called Inverter. In the SPMC such conversion is performed when the input source is DC. During stage 1 the switches S_{A1} and S_{D1} while in stage 2 S_{B1} and S_{C1} is turned on shown in Figure-4.

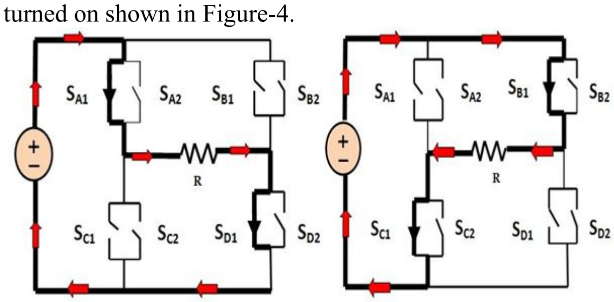

Figure-4. Modes of SPMC as Inverter.

C. SPMC as AC voltage controller

AC voltage controller which converts fixed AC voltage into variable AC voltage. Simply it can be say as AC-AC converter. In the SPMC such conversion is performed when the input source is AC. During the first half cycle the switches S_{A1} and S_{D1} are turned on while in second half cycle the switches S_{D2} and S_{A2} are turned on shown in Figure-5.

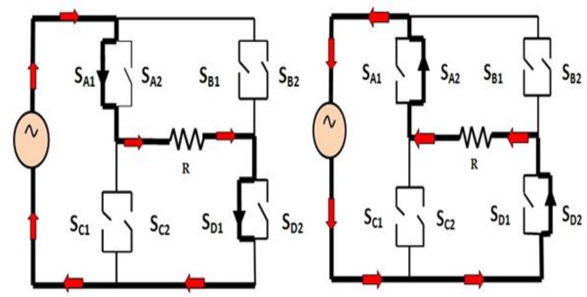

Figure-5. Modes of SPMC as AC-AC converter.

D. SPMC as frequency changer (cyclo-converter)

Frequency changer is a converter which converts AC power at one frequency into desired load frequency. The SPMC acting as cyclo-converter can perform both step-up and step-down operations when the input source is AC. The switches S_{A1} and S_{D1} are turned on during stage a while in stage b the switches S_{C2} and S_{B2} are turned on. During stage c the switches S_{B1} and S_{C1} are turned on and in stage d the switches S_{D2} and S_{A2} are turned on as shown in Figure-6.

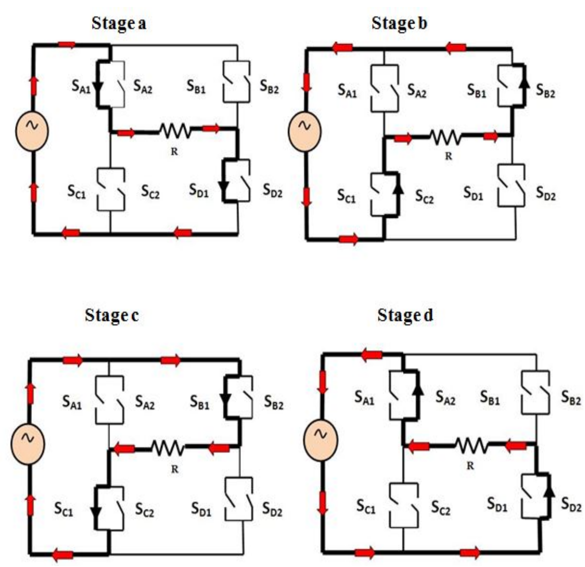

Figure-6. Four stages of SPMC as Frequency changer.

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Table-1. Switching Sequence of four types of converters.

OPERATION	STAGES	SWITCHES
RECTIFIER	1 2	S_{A1}, S_{D1} S_{C2}, S_{B2}
INVERTER	1 2	S_{A1}, S_{D1} S_{B1}, S_{C1}
AC VOLTAGE CONTROLLER	1 2	S_{A1}, S_{D1} S_{D2}, S_{A2}
CYCLO CONVERTER 25Hz	1 2 3 4	S_{A1}, S_{D1} S_{C2}, S_{B2} S_{B1}, S_{C1} S_{D2}, S_{A2}
CYCLO CONVERTER 100Hz	1 2 3 4	S_{A1}, S_{D1} S_{B1}, S_{C1} S_{C2}, S_{B2} S_{D2}, S_{A2}

Similarly the output voltage can be obtained for higher frequency in cyclo-converter

E. SPMC as DC-DC converter (chopper)

DC-chopper is device which converts fixed DC input into controllable DC as the output. In this section SPMC as dc chopper is explained with RLE load. Here is has four modes of operation.

First quadrant (Q1)

In this quadrant, both V_L and I_L are positive and the flow of load current from source to load. The condition is achieved when the switches S_{A1} and S_{D1} are turned on while turning off of the switch S_{A1}, the switch S_{C2} is turned-on to provide the freewheeling operation along with the switch S_{D1} that complete the loop for returning path of current. In this cycle, the switches S_{A1} and S_{D1} are maintained always on when the switch S_{C2} is turned off as shown in Figure-7.

Second quadrant (Q2)

In this quadrant, V_L is positive and I_L is negative while the load current flows out of the load. The condition is achieved when the switches S_{C1} and S_{D2} are turned on, the voltage E will drive the current through the load. The switch S_{A2} is turned on, the load will feedback the energy to the source through the switch S_{A2} and S_{D2} during turn-off of the switch S_{C1} as shown in Figure-7.

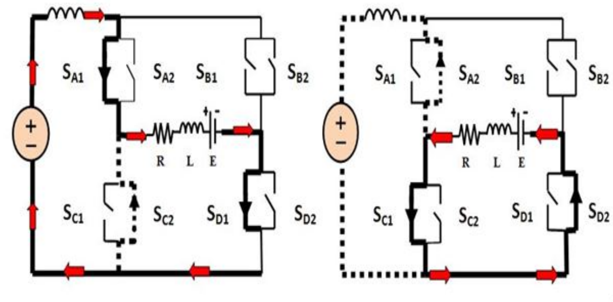

Figure-7. First and Second quadrant of DC-DC converter.

Third quadrant (Q3)

In this quadrant, both V_L and I_L are negative and the load current flows from source to load. The condition is achieved when the switches S_{B1} and S_{C1} are turned on while turning off of the switch S_{B1}, the switch S_{D2} is turned on to provide the freewheeling operation along with the switch S_{C1} that complete the loop for returning path of current. In this cycle, switches S_{B1} and S_{C1} are maintained always on when the switch S_{D2} is turned off shown in Figure-8.

Fourth quadrant (Q4)

In this quadrant, V_L is negative and I_L is positive while the load current flows out of the load. The condition is achieved when the switches S_{D1} and S_{C2} are turned-on, the voltage E will drive the current through the load. The switch S_{B2} is turned on, the load will feedback the energy to the source through the switch S_{B2} and S_{C2} during turn-off of the switch S_{D1} as shown in Figure-8.

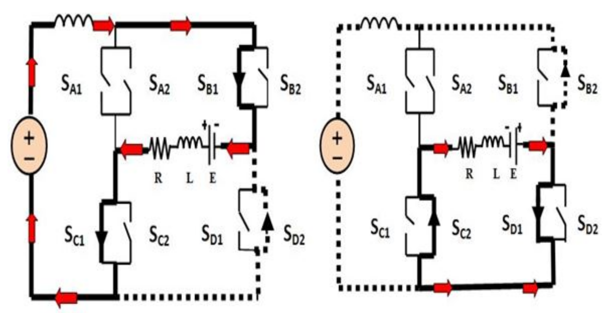

Figure-8. Third and Fourth quadrant of DC-DC converter.

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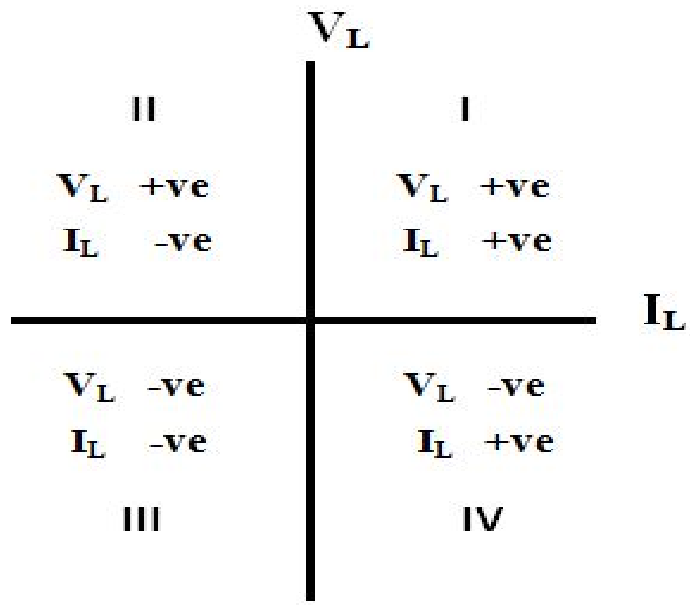

Figure-9. All quadrant of DC-DC converter.

Table-2. Switching States of DC-DC converter.

Switch	First quadrant	Second quadrant	Third quadrant	Fourth quadrant
S_{A1}	On (Modulate)	Off	Off	Off
S_{A2}	Off	Feed back	Off	Off
S_{B1}	Off	Off	On (Modulate)	Off
S_{B2}	Off	Off	Off	Feed back
S_{C1}	Off	On (Modulate)	On (Continuous)	Off
S_{C2}	Freewheels	Off	Off	On (Continuous)
S_{D1}	On (Continuous)	Off	Off	On (Modulate)
S_{D2}	Off	On (Continuous)	Freewheels	Off

3. SIMULATION IMPLEMENTATION AND RESULTS

The simulation model of SPMC system is shown in Figure-10 and Figure-11. The SPMC as universal converter are shown for the Switching frequency 5kHz , Modulation ratio=0.5 and Duty cycle ratio=0.5.The simulated output results of SPMC as Rectifier, AC voltage Controller, inverter, Frequency Changer and four quadrant chopper are shown in the following from Figure-14 to Figure-19.

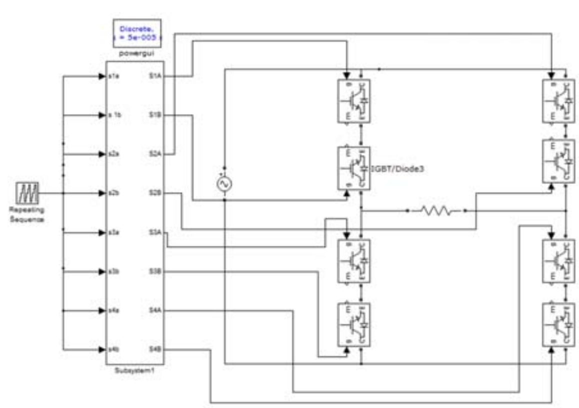

Figure-10. Simulation model SPMC circuit.

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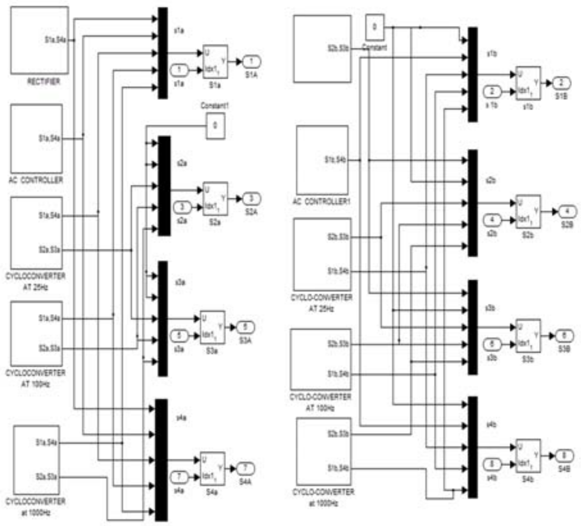


Figure-11. Simulation of subsystem.

The values used in PWM generator is carrier frequency (f_c) =5kHz, Sample time=5µs, Modulation ratio=0.5, output voltage frequency=50Hz, output voltage phase =0°

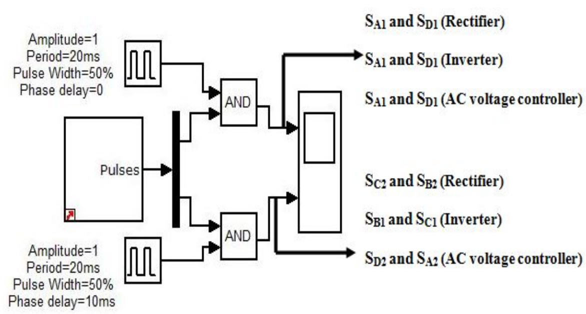


Figure-12. Pulse generation for firing angle 0°.

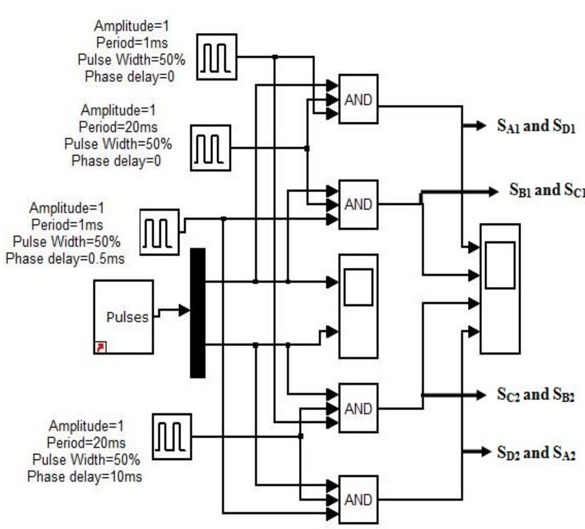


Figure-13. Pulse generation of cyclo-converter for output frequency 100Hz.

Table-3. Input Parametes.

Input	AC	DC
Supply Voltage	100V	100 V
Supply Frequency	50Hz	-
Load	R=50 Ω	

Table-4. Parametes for DC-DC converter.

Supply voltage	100V
Boost Inductor	0.01µH
Load	R=50 Ω L=0.05mH E=5V

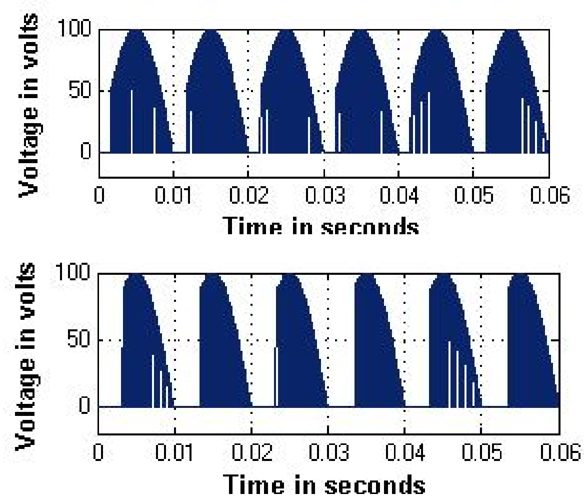


Figure-14. Output voltage of rectifier for firing angle 30° and 60°.

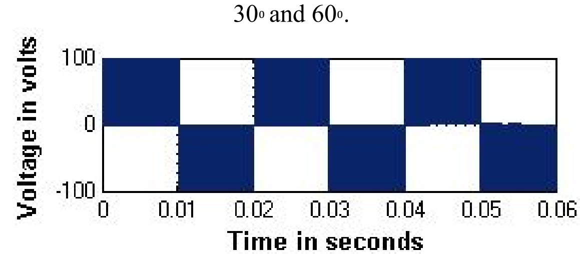
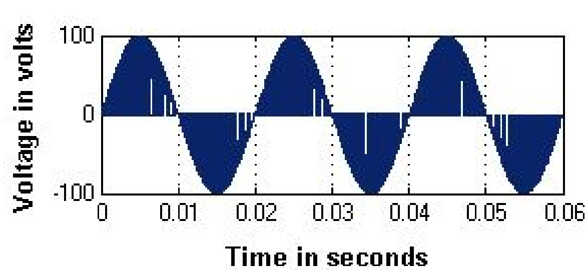


Figure-15. Output voltage of Inverter.



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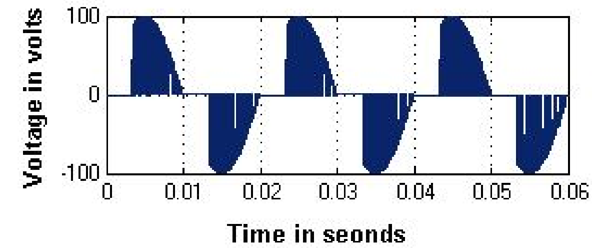

Figure-16. Output voltage of AC voltage controller for firing angle 0° and 60°.

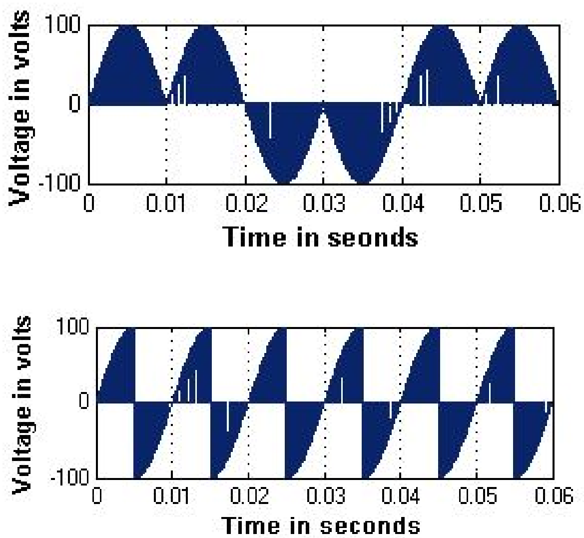

Figure-17. Output voltage of Frequency changer for output frequency 25Hz and 100Hz.

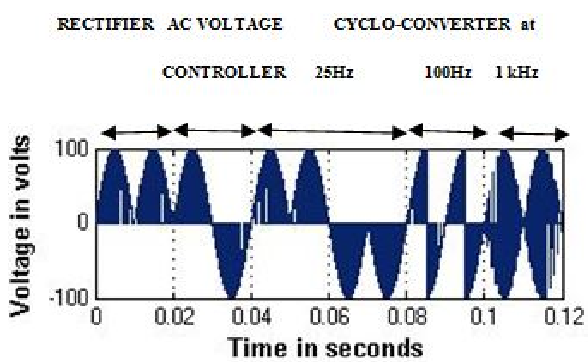

Figure-18. Output voltage of Rectifier,AC voltage controller and Frequency changer at 25Hz, 100Hz ,1kHz.

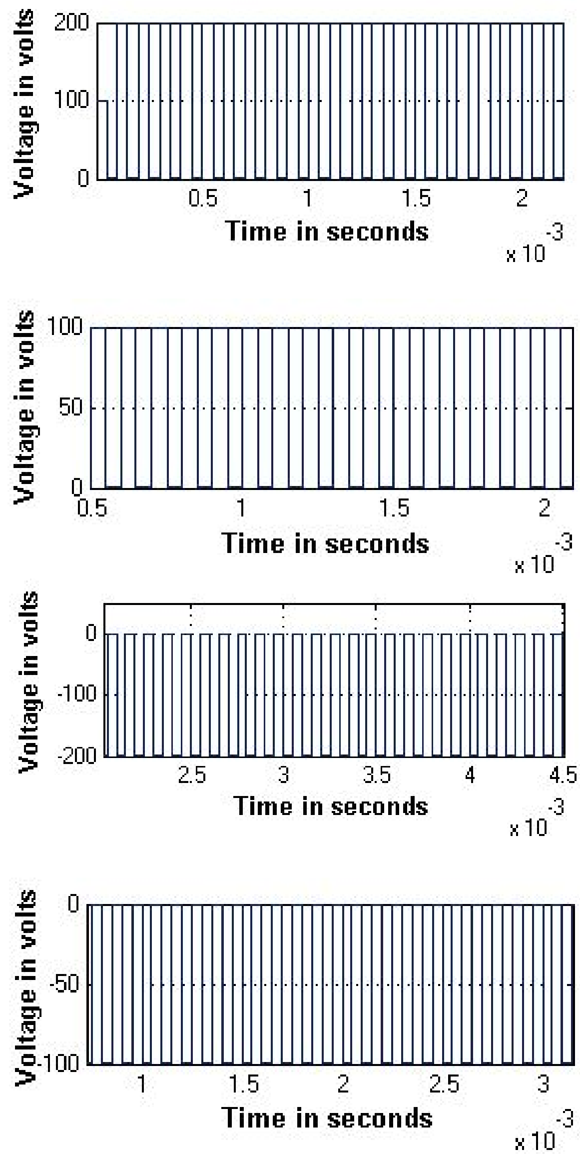

Figure-19. Output volage of I, II, III and IV quadrants of DC-DC converter.

4. CONCLUSIONS

The performance of Single Phase Matrix Converter as AC-DC converter, DC-AC converter, AC-AC converter, DC-DC is studied. The Simulation results of Single Phase matrix Converter proves that it can be operated as traditional Single phase power converter. The output voltage waveforms shown for rectifier, AC voltage controller, inverter, Cyclo-Converter for R load and four quadrants DC Chopper for RLE load. From the detailed observation it is well known that Single Phase Matrix Converter can avoid the need of other conventional converters topologies in future. The multi-operation of SPWM based SPMC system is simulated in MATLAB/Simulink 2016 software and the results proves the performance of the SPMC.

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REFERENCES

[1] Wheeler P.W., Rodriguez J., Clare J.C., Empringham L., Weinstein A. 2002. Matrix Converters: A Technology Review. IEEE Trans. Ind. Electron. 9(2): 276-282.

[2] S. Hamzah M.K. 2002. Modelling and Simulation of a Single-Phase AC-AC Matrix Converter Using SPWM. Proc. Of Student Conference on Research And Development, Scored 2002. pp. 286-289.

[3] Gyugyi B. R. Pelly. 1996. Static Power Charges, Theory, Performance and Application. John Wiley & Son Inc.

[4] Venturini M and Alensina A. 1980. The Generalized Transformer: A New Bidirectional Sinusoidal Wave Form Frequency Converter with Continuously Adjustable Input Power Factor. IEEE Power Electron. Spec. Conf. Rec. pp. 242-252.

[5] Zuckerberger A., Weinstock D., Alexandrovitz A. 1997. Single Phase Matrix Converter. IEE Proc. Electr. Power Appl. 144(4): 235-240.

[6] Hosseini S.H.; Babaei E. 2001. A New Generalized Direct Matrix Converter. Industrial Electronics, 2001. Proc. ISLE 2001. 2: 1071-1076.

[7] Firdaus S., Hamzah M.K. 2002. Modelling and Simulation of a Singlephase AC-AC Matrix Converter Using SPWM. Student Conference on Research and Development 16-17 July 2002, Scored 2002. pp. 286-289.

[8] Idris Z, Noor S.Z.M. and Hamzah M.K. 2005. Safe Commutation Strategy in Single-phase Matrix Converter. Proc. of IEEE Sixth International Conference PEDS 2005, Kuala Lumpur, Malaysia. pp. 886-891.

[9] Idris Z, Hamzah M.K. and Saidon M.F. 2006. Implementation of Single-Phase Matrix Converter as a Direct AC-AC Converter with Commutation Strategies. Proc. of 37th IEEE Power Electronics Specialists Conference, PESC„ 06, pp. 1-7.

[10] Baharom R., Hasim A.S.A, Hamzah M.K. and Omar M.F. 2006. A New Single-Phase Controlled Rectifier Using Single-Phase Matrix Converter. Proc. of first International Power and Energy Conference PECon 2006, Putrajaya, Malaysia. pp. 453-459.

[11] Hamzah M.K., Noor S.Z.M, and Shukor S.F.A. 2006. A New Single-Phase Inverter using Single- Phase Matrix Converter Topology. Proc. of first International Power and Energy Conference PECon 2006, Putrajaya, Malaysia. pp. 459-464.