Simulation of Single Phase Matrix Converter Using SPWM for Low Frequency Motor Control Application

P. Jenitha Deepa
(*Assistant Professor*): Department of Electrical and
Electronics Engineering
Saranathan College of Engineering
Tiruchirappalli,India

M. Rizwana[1], N. Thaslima[2], S. Priyadharshini[3]
V.Priyadharsini[4]
(UG Graduate): Department of Electrical and
Electronics Engineering
Saranathan College of Engineering
Tiruchirappalli,India

***Abstract*— This paper presents the concept of Single Phase Matrix Converter topology for the conversion of AC-AC with reduced frequency operation. The main advantage of matrix converter is bi-directional energy flow. The circuit comprises of four ideal switches. The output of this converter is fed into the single phase induction motor. The Sinusoidal Pulse Width Modulation (SPWM) scheme is used to incorporate the output of both open loop and closed loop model for various frequency levels. The topology with required switching strategy is then modelled using MATLAB/SIMULINK.**

Keywords—Single Phase Matrix Converter (SPMC), Sinusoidal Pulse Width Modulation (SPWM), Insulated Gate Bipolar Transistor (IGBT).

I. INTRODUCTION

The electrical machine is one that converts electrical energy into mechanical energy. Drive systems are widely used in many applications such as fans, pumps, paper and textile mills, elevators, electric vehicle and subway transportation, home appliances, wind generation systems, servos and the multiple conversion stages and the intermediate robotics, computer peripherals, steel and cement mills, ship propulsion, etc. Among all types of machine, Induction machine is commonly used in industry. Mostly, all industrial applications depends on ac to ac power conversion and the ac to ac converters takes Power from one ac system and delivers it to another ac system with the waveform of different amplitude, frequency or phase.

These converters are becoming popular due to the availability of better switching devices. The Matrix converter was first proposed by Gyugyi in 1976 [1,2].Then it was introduced by Venturini and Alesina in 1979 is the most general converter-type in the family of ac–ac direct converters [3].SPMC can perform 4 type of power conversion AC-AC [4],AC-DC [5],DC-AC [6],DC-DC [7] using the same circuit model. This type of converters has the advantages of bi-directional power flow, sinusoidal input and output waveforms, minimal requirement for reactive energy storage components [8,9]. The ac to ac matrix converters are commonly classified into two categories, one is direct converters and another one is indirect converters. Direct ac–ac matrix converters have a number of advantages when compared to dc link converters. In such converters, power is converted from fixed AC voltage and frequency to variable AC voltage and frequency without any intermediate dc link. The matrix converter has a disadvantage that the maximum output voltage is limited to 86.6% of the input voltage. [10]. The power circuit of a single-phase direct ac–ac converter feeding an induction motor is shown in Fig (1).

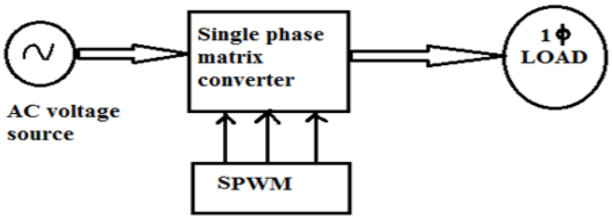

Fig. 1. Block diagram of single phase matrix converter

The circuit performs the frequency and voltage conversion in a single step without using storage elements. Moreover with bi-directional switches, the converter also enables regenerative operation which is a desirable feature in motor control applications [11]. However, dc converters are not able to perform bi-directional power flow without making the input side of the converter controllable [12]. Matrix converter is characterized by sinusoidal waveform that shows the input and output switching frequencies. Generally, simulations were performed to predict the behavior and nature of a circuit .The SPWM block is used to give a pulse to the IGBT of the single phase matrix converter. As compared to conventional drive there is potential for increased power/weight and power/volume ratios. This topology is to simulate the single phase direct matrix converter with reduced frequency. The input is fed from a single phase ac voltage source. The SPWM block is used to give a pulse to the IGBT of the single phase matrix converter. The output of this topology is fed to the single phase load. Results of the simulation are presented to verify the feasibility of given technique.

II. BIDIRECTIONAL SWITCHES

The IGBT was used for its high switching capabilities and high current carrying capacities which are enviable for high power application. The bidirectional switch is given in Fig (2)

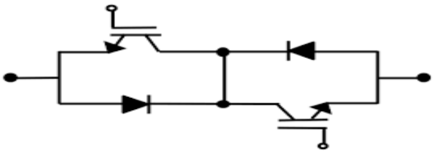

Fig. 2. Bidirectional switch

Matrix converter requires the use of bidirectional switches capable of blocking voltage and conduction current in both directions. In the absence of bidirectional switch module, the common emitter anti-parallel IGBT with diode pair can be employed. The diodes provide reverse blocking accomplishment to the switch module [13].

III. SINGLE PHASE MATRIXCONVERTER

The SPMC consists of four ideal bidirectional switches as displayed in Fig (2). In which the source input is coupled with the load. The switches can be denoted as S1, S2, S3, and S4 for the respective four switches where “a” is denoted as forward direction and “b” is denoted as its reverse direction of each switch. The switches s1a, s4a, s2b, s3b conducts for positive half cycle as shown in the Fig (3) and Fig (5). The s1b, s4b, s2a, s3a conducts for negative half cycle as shown in the Fig (4) and Fig (6). Each switch can accomplish conduction current in both directions, blocking forward and reverse voltages. The input and output voltage of SPMC is given by the equation (1) and (2) respectively with loads represented in (3).

$$V_i(t) = \sqrt{2}V_i \sin\omega_i t \qquad \ldots (1)$$

$$V_o(t) = \sqrt{2}V_o \sin\omega_o t \qquad \ldots (2)$$

$$V_o(t) = Ri_o(t) + L\frac{di_o}{dt}(t) \qquad \ldots (3)$$

The fundamental component of output voltage is given by the equation (4)

$$f_o = f_m - f_i \qquad \ldots (4)$$

Where f_m the modulation frequency and f_i is the input frequency [14].The four bidirectional switches S1 to S4 “a” or “b” represent the driver one and two respectively according to the following guidelines:

- S1a and S4a will manage the current flow during positive cycle of the input source shown in Fig (3).
- S1b and S4b will manage the current flow during negative cycle of the input source shown in Fig (4).
- S2b and S3b will manage the current flow during positive cycle of the input source shown in Fig (5).
- S2a and S3a will manage the current flow during negative cycle of the input source shown in Fig (6).

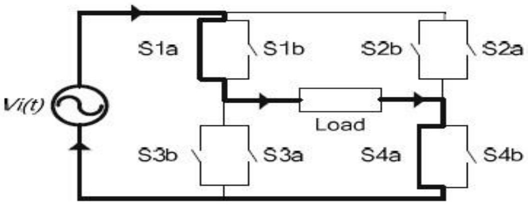

Fig. 3. For positive cycle

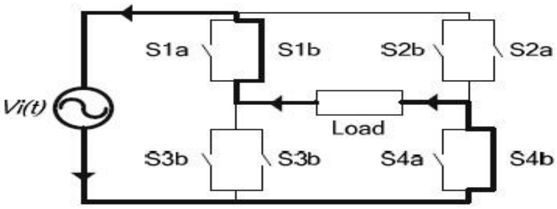

Fig. 4. For negative cycle

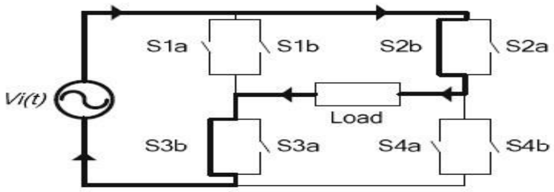

Fig. 5. For positive cycle

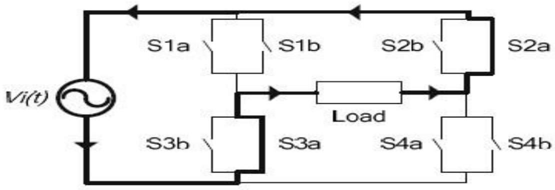

Fig. 6. For negative cycle

Representation of SPMC with reduced frequency operation requires different bidirectional switching arrangements depending on the desired output frequency [15]

IV. SINUSOIDAL PULSE WIDTH MODULATION

The Sinusoidal Pulse Width Modulation (SPWM) is a well-known technique in power electronics. The switches in the voltage source can be turned on and off as required. Generation of the desired pulses is achieved by comparing the high-frequency triangular ‘carrier’ signal (Vc) with a sinusoidal reference signal (Vref) of the desired frequency is shown in the Fig (7).

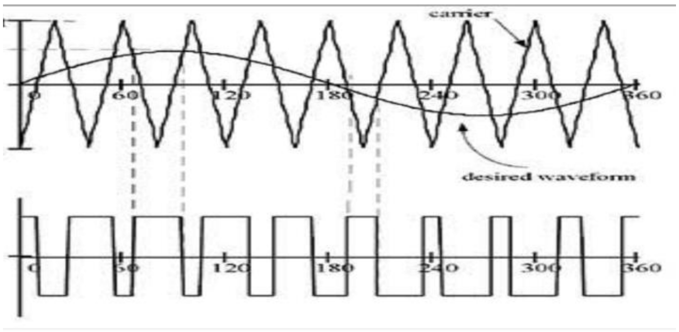

Fig. 7. Sinusoidal Pulse Width Modulation

Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative voltage is applied at the output [16]. The crossover points are used to detect the switching instants. The output voltage of the converter is controlled by SPWM, but the frequency of the converter is changed by controlling the duration of operation of the switch [17]. The value of output voltage is proportional (or) equivalent to modulation index (mi) .The modulation index (mi) is the ratio of the reference signal (Vref) to that of the carrier signal (Vc) [18] .The switching pattern for the required frequency is given in the Table (1).

TABLE I SWITCHING PATTERN FOR VARIABLE FREQUENCY

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

V. SIMULATION

The model is verified through simulation using MATLAB/SIMULINK. The open loop simulation model is displayed in Fig (8) and its corresponding subsystem of SPWM block is shown in the Fig (9). The closed loop simulation model is displayed in Fig (10) and its corresponding subsystem of SPWM block is shown in the Fig (11). The desired output derived from simulation method related to SPMC for different frequencies and the motor for the speed in rpm is shown in figure from Fig(12) to Fig(21).

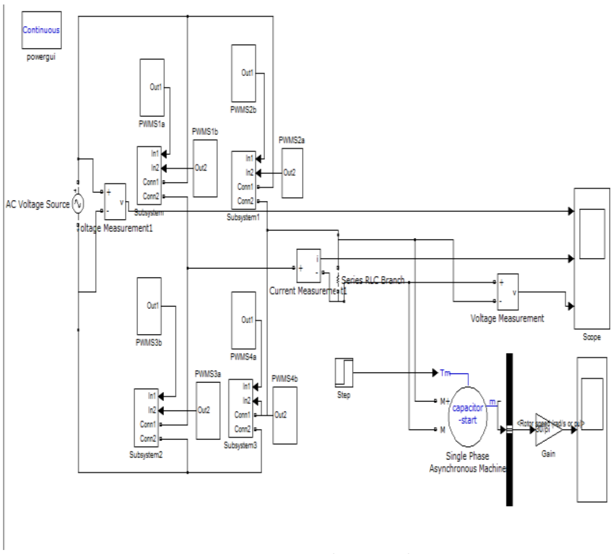

Fig. 8. Simulink model of SPMC for open loop

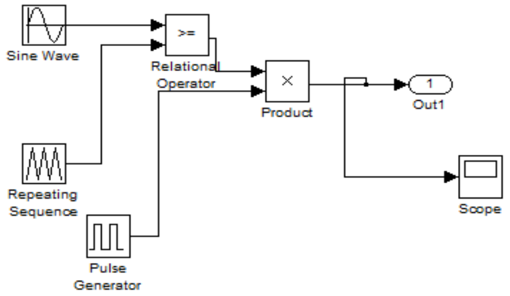

Fig. 9. Sub Block of Sinusoidal Pulse Width Modulation for open loop

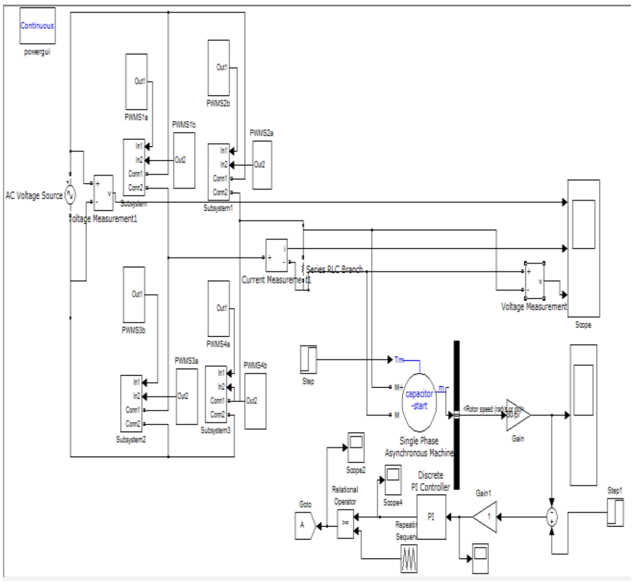

Fig. 10. Simulink model of SPMC for closed loop

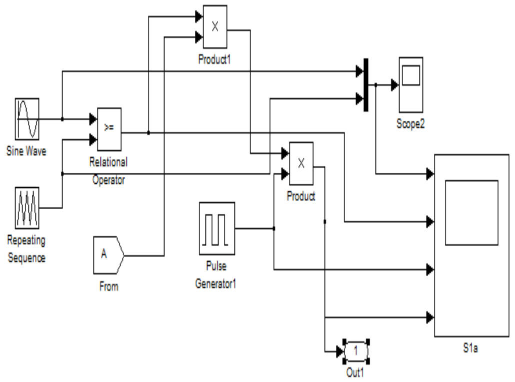

Fig. 11. Sub Block of Sinusoidal Pulse Width Modulation for closed loop

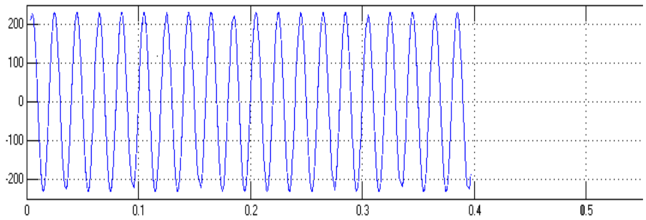

Fig. 12. Input voltage waveform

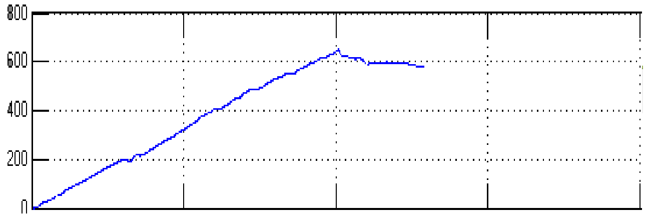

Fig. 13. Speed (in rpm) at 25HZ for open loop

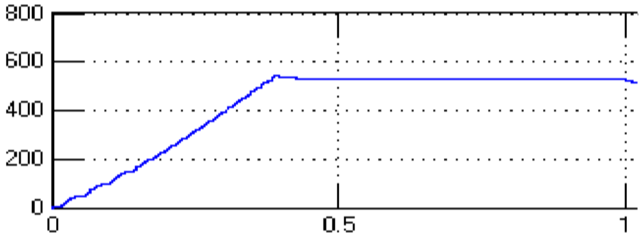

Fig. 14. Speed (in rpm) at 25 Hz for closed loop

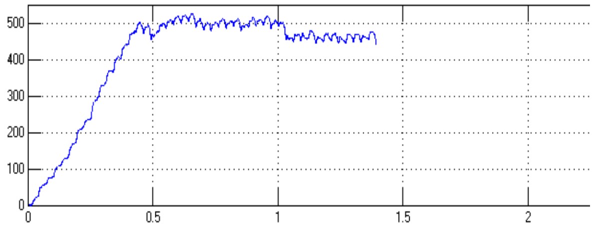

Fig. 15. Speed (in rpm) at 16.67 Hz for open loop

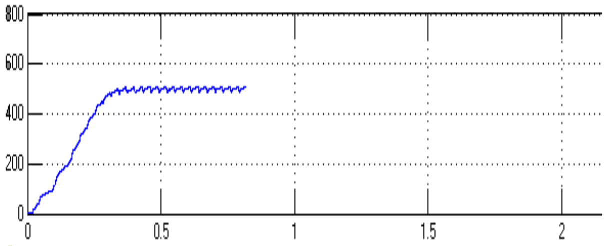

Fig. 16. Speed (in rpm) at 16.67 Hz for closed loop

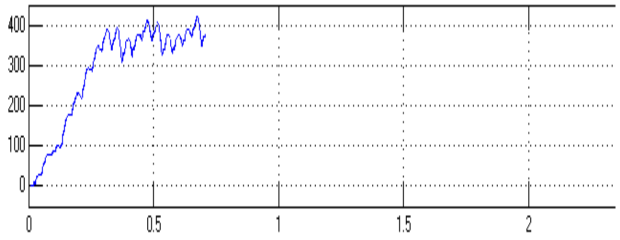

Fig. 17. Speed (in rpm) at 12.5 Hz for open loop

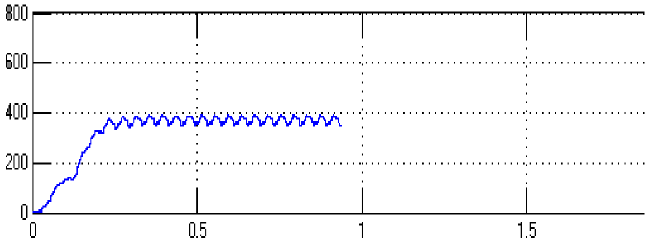

Fig. 18. Speed (in rpm) at 12.5 Hz for closed loop

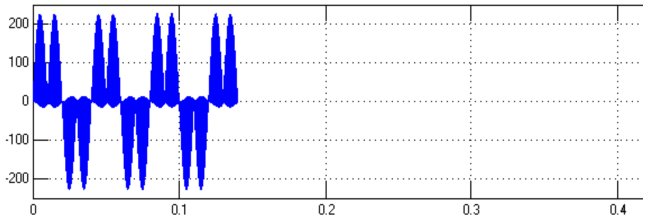

Fig. 19. Output voltage waveform at 25 Hz

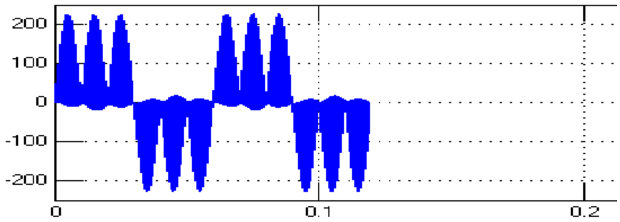

Fig. 20. Output voltage waveform at 16.67 Hz

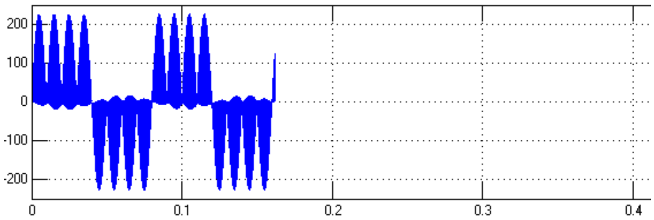

Fig. 21. Output voltage waveform at 12.5 Hz

VI. CONCLUSION

It has been illustrated that the single-phase matrix converter can be simulated and recognized by suitable switching schemes, where IGBTs are used as the main power switching device. When fed from the mains at constant frequency and amplitude, the converter is capable of synthesizing a constant output voltage with variable frequency. From the results obtained, it has been shown that by varying the output frequency the speed of the asynchronous motor can be varied. The output waveform has been synthesized using Sinusoidal Pulse Width Modulation.

VII. REFERENCES

[1] Venturini M, Alesina A (1980) the generalized transformer: a new bi-directional wave form frequency converter with continuously adjustable input power factor. IEEE PESC 1980, pp 242–252.

[2] Venturini M (1980) a new sine wave in sine wave out conversion technique eliminates reactive elements. In: Proceeding of Powercon7, pp E3–1, E3–15.

[3] Gyugyi L, Pelly BR (1976) Static power chargers theory, performance and application. Wiley, New York.

[4] VytlaSatish,Sravan Kumar Konathala,A.Uday Ravi Kiran"Design and Implementation of Single phase Matrix Converter for Cycloconverter Operation" in IJERT Volume-3, Issue-1 Jan-2014.

[5] P.Jenitha Deepa, S.Radhikha "Analysis of Single Phase Buck - Boost Matrix Converter with Reduced number of Switches" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 9 No.24 (2014) pp.

[6] M.S.Aspalli,SyedaRumanaMohammadi "Application of Single Phase Matrix Converter Topology to an Uninterruptible Power Supply Circuit" International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308,Volume 03 ,special issue 03-May-2014.

[7] Rahul Kumar et al "Modelling and Simulation of Matrix Converter Based DC-DC Converter" International Conference ICEETS,2013.

[8] Wheeler PW, Clare JC, Empringham L, and Bland M, Kerris KG (2004) Matrix converters: a vector controlled MCT matrix converter induction motor drive with minimized commutation times and enhanced waveform quality. IEEE Indus Appl Mag (JanFeb):59–65.

[9] Altun H, Sünter S (2003) Matrix converter induction motor drive:modelling, simulation and control.SElectrEng 86:25–33.

[10] RajaniK,RachananjaliK,Bala Krishna K,and V S L Tirumala "Speed Control of 1ϕInduction Motor Using 1ϕMatrix Converter"in special issue of IJCTA,9(29),2016,pp.267-271.

[11] Jun-Koo Kang et al "Analysis and Evaluation of bidirectional power switching losses for matrix converter drive"in Industrial application conference,2002.

[12] Sasikumar S,Krishnamoorthy K "A literature survey on Bidirectional DC to DC converter", Volume iv,issue X,Oct 2015.

[13] Agarwal,Anushul and Vineeta Agarwal. "Staircase Modulated AC-AC Converter",2010 International Conference on Power Control and Embedded Systems,2010.

[14] B.Vamsi Krishna "Realization of AC-AC Converter Using Matrix Converter" in IJAREEIE Vol. 3, Issue 1, January 2014.

[15] Azilah Saparon. " Modelling and Simulation of Single Phase Matrix Converter as a Frequency Changer with Sinusoidal Pulse Width Modulation Using MATLAB/SIMULINK"2006 IEEE International Power and Energy Conference.

[16] P.Jenitha Deepa, R. Ramya "Analysis of Variable frequency Single-Phase Matrix Converter using SPWM Technique".

[17] Z., Hamzah, M. K., Hamzah, N. R., "Modelling & Simulation of a new Single-phase to Single-phase Cycloconverter based on Single-phase Matrix Converter Topology with Sinusoidal Pulse Width Modulation Using MATLAB/Simulink" International Conference on Power Electronics and Drives System, 2005, IEEE PEDS 2005, Vol. 2 28-01 Nov. 2005, pp. 1557-1562.

[18] Dilipkumar and InduPandey,"Implementation of single phase matrix converter as a cycloconverter" in special issue of Imperial Journal of Interdisciplinary Research (IJIR) volume 2 issue-5,2016.