

# Pulse Width Modulator for Voltage Regulation in Voltage Source Inverter

K.Dhivya<sup>[1]</sup>, R.Anandaraj<sup>[2]</sup>

PG Scholar<sup>[1]</sup>, Associate Professor<sup>[2]</sup>

Department of Electrical and Electronics Engineering  
E.G.S Pillay Engineering College, Nagapattinam  
Tamil Nadu – India

## ABSTRACT

Pulse Width Modulated (PWM) voltage source inverters (VSIs) are extensively used in industrial and domestic applications. The versatile natural sampled sinusoidal PWM (SPWM) method can perform output voltage control with acceptable indices. In these PWM-VSI, the coarse voltage regulation is done with change in modulation depth while fine voltage regulations have not been addressed by other authors. This paper proposes modified carrier based SPWM for achieving fine voltage regulation. The effectiveness is demonstrated using MATLAB/ Simulink for the single phase full bridge VSI. The modified carrier PWM scheme improves the fundamental voltage value, reduces the THD and suppresses the lower order harmonics.

**Keywords:-** Single-phase full bridge voltage source inverter, Pulse dropping, Carrier Phase Shift Keying PWM, duty cycle, modulation index, nonlinear modulation, SPWM.

## I. INTRODUCTION

One of the solutions to enhance the harmonic free environment in high power converters is to use PWM control techniques. Instead of having a continuous pulse as in classical square wave inverter, having multiple pulses in the output can have control over harmonic content and the rms value of the voltage across the load without changing the input dc. The process of varying the width of these pulses is known as pulse width modulation. This control strategy accomplished by generating gate signal by comparing reference signal of frequency ( $f_r$ ) and magnitude ( $A_r$ ) with carrier triangular signal of frequency ( $f_c$ ) and amplitude ( $A_c$ ).

PWM method has some advantages. The control of output voltage can be achieved easily without any complicated circuitry. Lower order harmonics in the output can be eliminated or minimized along with the voltage control. As higher order harmonics can be filtered easily, the filtering requirements become simple. PWM

method has fundamental magnitude restriction. Problem can be solved by over modulation by increasing the duty cycle.

In 1993, Giovanni have proposed the reduction of gain in the pulse dropping region restricts the range of speed and torque regulation in motor control applications. In 1999, Chen and Cheng have proposed an analog based PWM scheme to eliminate lower order harmonics caused by non-constant dc voltage. In 1981 Mazzucchelli and Puglesi have developed subharmonic method. For medium and high power inverter applications, maximum switching frequency is caused by turn off time. Conduction, and switching losses of the device, a PWM technique with lower switching frequency is required.

In this paper is to propose a PWM modulator using CPSKPWM (Carrier Phase Shift Keying Pulse Width Modulation) provide improved inverter performance compared to the SPWM technique. Proposed method eliminates lower order harmonics reduce, THD.

## II. VOLTAGE SOURCE INVERTER

Basic single phase full bridge inverter is shown in fig.1, which consists of four switches namely S1, S2, S3 and S4. A switching sequence for the single phase full bridge inverter, shown in fig.1

PWM scheme presented in this study are assumed to be synchronous PWM. In fig. 2 sinusoidal wave is a conventional one and considered as reference wave and triangular wave is modified one and considered as carrier wave.

Input of the single phase full bridge inverter is dc and output is variable AC voltage variable frequency. Variable output voltage is obtained by varying the input voltage and maintaining the inverter gain. In case the input is fixed the inverter gain is varied to provide variable AC output voltage. The poor dc source utilization has well known remedy called over-modulation (non-linear modulation), to increase the fundamental frequency component in the output voltage;  $M_a$  has to be increased beyond 1.0. This is called over-modulation

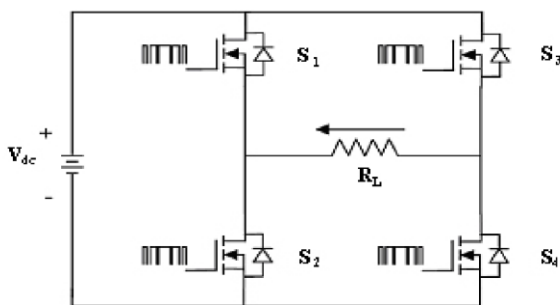


Fig. 1. Single-phase full-bridge inverter

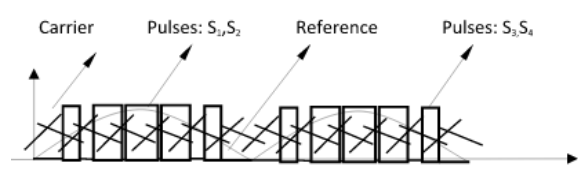


Fig.2. Gate pulse generation

## III. PROPOSED PWM TECHNIQUE

The conventional and modified SPWM techniques relies on triangular (carrier)-sine (reference) comparison. The triangular waveform can be generated in many choices with minor differences. Modification of triangular carrier wave is the basic principle of proposed switching strategy, grouping the two or more carrier wave in the middle of the reference wave, which increase the width of the pulses. Introduces a control degree of non-linear sampling to maximize PWM fundamental voltage while minimizing THD. Reference signal i.e., sinusoidal wave is conventional and the carrier is modified one.

Triangular wave is grouped either “W” shape or “M” shape. Fig. 3 shows the conversion of W cycle group to M cycle group and fig. 4 shows the conversion of M cycle group to W cycle group. An optimal case may require n number such conversions.

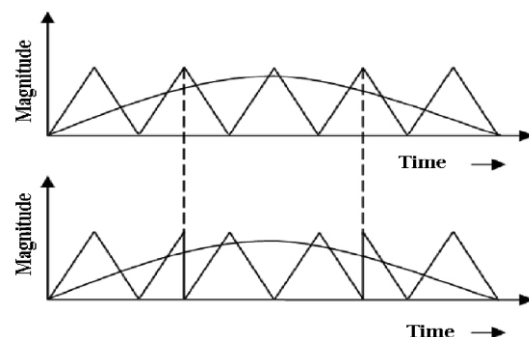


Fig. 3. W to M conversion [ $M f = 5$  (odd)].

Shows the fig. 3,4 both cases, conversion take place which increases the width of PWM pulses in the center region while the other regions are unaffected. This conversion not only in the middle region also in the remaining regions.

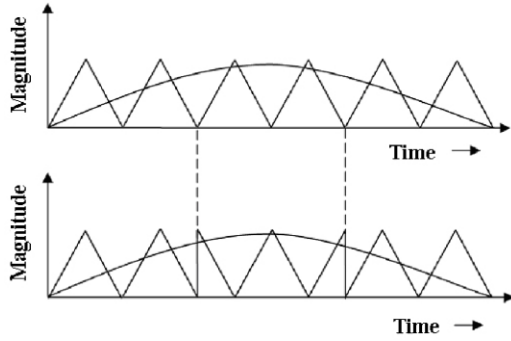


Fig. 4. M to W conversion [ $M_f=6$  (even)]

**IV. SIMULATION STUDY**

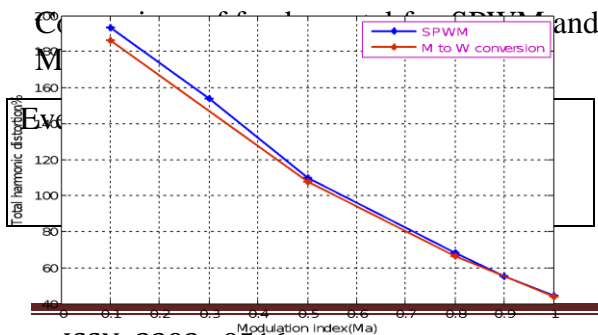
Proposed work performance is evaluated using MATLAB/ Simulink software. Fundamentals of the single phase inverter the range number of pulses are analyzed using MATLAB. Input of the inverter is 400 V dc. Table II and III shows the fundamental and THD range for odd and even of pulses.

TABLE I

Comparison of fundamental for SPWM and Modified technique; Odd  $M_f$

Odd $M_f$	Fundamental magnitude	
	SPWM	Modified Technique
9	284.5	284.3
11	285.1	282.7
13	282.8	282.3
15	282.1	283.1
17	284.7	285.8
19	277.8	277.7
21	284.1	284.2

TABLE II



	Technique	
	8	285.1
10	274.3	283.4
20	273.3	279.4
30	281.6	286.6
40	287.3	289.3

Odd  $M_f$  having same result compared to SPWM. In even  $M_f$  provide better result than SPWM

2) Influence of  $M_a$  and  $M_f$  on Fundamental and THD Variation

This is a unique characteristic, which reflects the control parameter directly on most required beneficial indices viz. fundamental and THD as shown in Figures 5 and 6 with modulation index. The fundamental voltage increases as the modulation depth increases, and also CPSKSPWM gives more fundamental (2V for  $M_a=1.0$ ,  $M_f=10$  and  $V_{dc}=400V$ ) over the entire range of modulation depth, provides the simple means of controlling the output voltage.

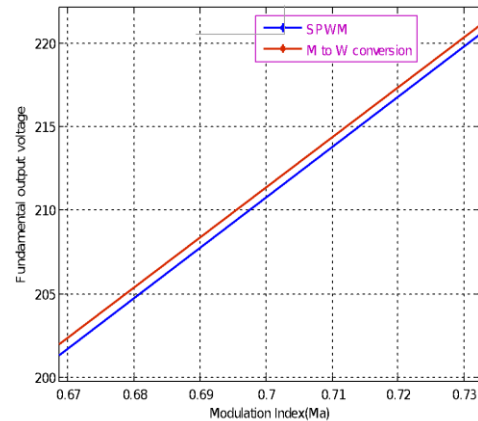


Fig. 5. Modulation Index Vs Fundamental

Fig. 6. Modulation Index Vs THD%

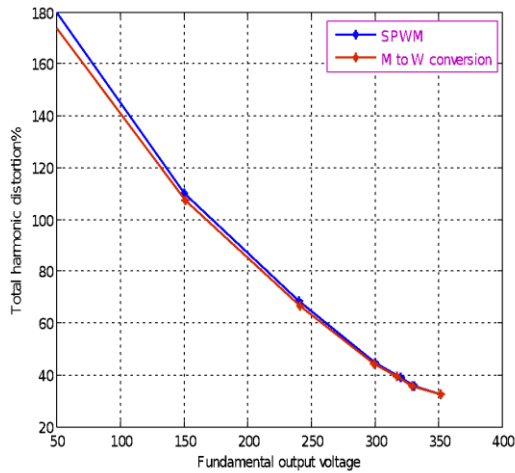


Fig. 7. Fundamental vs THD

Fig. 8 depicts the relationship of switching frequency and fundamental of inverter. Varying the switching frequency of the inverter modified technique provide higher fundamental then SPWM technique. Fig 9 shows THD range for SPWM and Modified technique. SPWM technique gives higher THD and modified technique gives low THD.

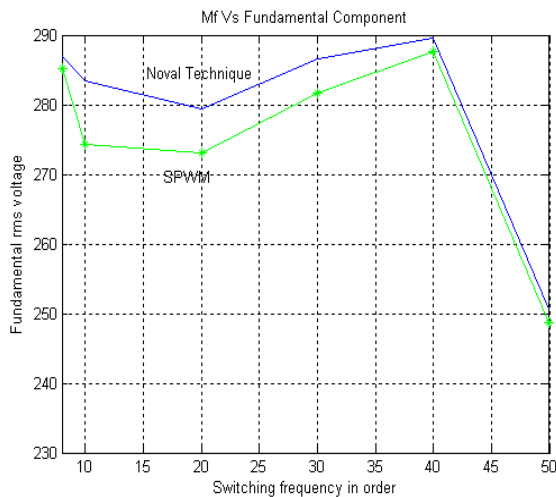


Fig. 8. Switching frequency vs fundamental

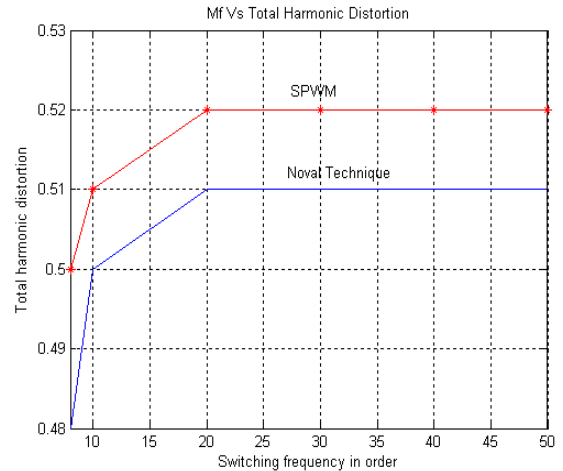
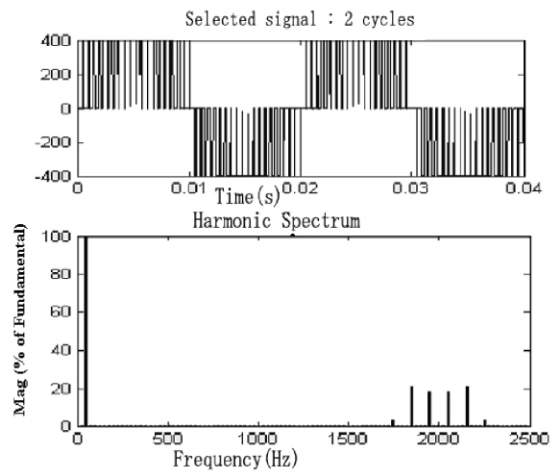


Fig. 9. Switching frequency vs THD

Fig 10 shows the output voltage and harmonic spectrum of SPWM and modified technique. Proposed method eliminates the higher order harmonics. Reduced harmonics can be obtained by over modulation( non linear) method.



(a)

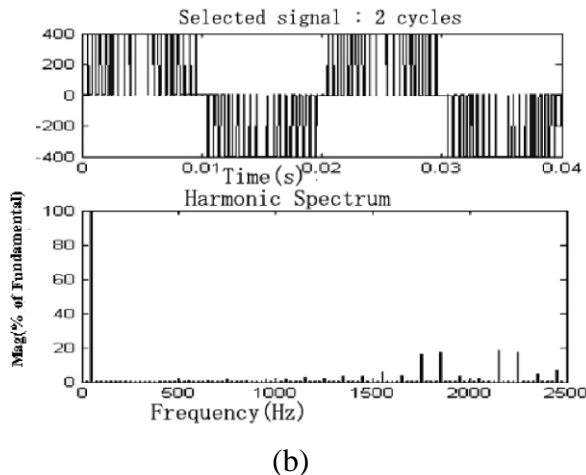


Fig. 10. Output voltage and harmonic spectrum  
(a) SPWM (b) Modified technique

## V. CONCLUSION

It has been outlined and illustrated that the PWM modulator is advanced method that could be used to perform the functions in inverter applications. The result of proposed work for a given switching frequency in a single phase full bridge voltage source inverter improve the fundamental voltage value compared to existing switching strategy. This proposed method extends the fundamental of inverter and also reduce the harmonics. Main advantage of this method it does not require different switching strategy at different level of modulation index and does not affect the other characteristics of SPWM. This method also eliminates the lower order harmonics. Improvement in THD used in drive application where low speed operation is required.

## REFERENCES

[1] M. A. Boost and P. D. Ziogas, "State-of-art-carrier PWM techniques: A critical evaluation," *IEEE Trans. on Industry Applications*, vol. 24, no. 2, pp. 271-280, Mar./Apr. 1998.

[2] S. Jeevananthan, R. Nandhakumar, P. Dananjayan: Inverted Sine Carrier for Fundamental Fortification in PWM Inverters and FPGA Based Implementations, Serbian

Journal of Electrical Engineering, Vol. 4, No. 2, Nov. 2007, pp. 171 – 187

[3] J. Holtz, "Pulse width modulation-A survey," *IEEE Trans. On Industrial Electronics*, vol. 39, no. 5, pp. 410-420, Dec. 1992.

[4] R. J. Kerkman, D. Leggate, B. J. Seibel, and T. M. Rowan, "Operation of PWM voltage source- inverters in the overmodulation region," *IEEE Trans. on Ind. Electronics*, vol. 43, no. 1, pp. 132-140, Feb. 1996.

[5] Y. M. Chen and Y. M. Cheng, "PWM control using a modified triangle signal," *IEEE Trans. on Industrial Electronics*, vol. 1, no. 29, pp. 312-317, Nov./Dec. 1999.

[6] P. N. Enjeti, P. D. Ziogas, and J. F. Lindsay, "Programmed PWM techniques to eliminate harmonics: A critical survey," *IEEE Trans. on Industry Application*, vol. 26, no. 2, pp. 302-316, Mar./Apr. 1990.

[7] S. Y. R. Hui, S. Sathiakumar, and K. K. Sung, "Novel random PWM schemes with weighted switching decision," *IEEE Trans. on Power Electronics*, vol. 12, no. 6, pp. 945-952, Nov. 1997.

[8] S. Vadivel and G. Bhuvaneshwari, "A unified approach to the real time implementation of microprocessor-based PWM waveforms," *IEEE Trans. on Industrial Electronics*, vol. 6, no. 4, pp. 565-575, Oct. 1991.

[9] S. Jeevananthan, P. Dananjayan, and A. Mohamed Asif Faisal, "A HPWM method for thermal management in a full-bridge inverter With loss estimation and electro-thermal simulation," *AMSE Periodicals of Modeling, Measurement and Control – Series B*, vol. 73, no. 6, pp. 1-20, Dec. 2004.

[10] V. Jegathesan, J. Jerome: Non-traditional Method-based Solution for Elimination of Lower Order Harmonics in Voltage Source Inverter Feeding an Induction Motor Drive, Serbian Journal of Electrical Engineering, Vol. 5, No. 2, Nov. 2008, 273 – 283.

[11] Y. M. Chen and Y. M. Cheng, "Modified PWM control for the DCAC inverter with a non-constant voltage source," in *Proc. of IEEE Int. Conf. Power Electronics and Drive Systems, PEDS'99*, pp. 938-941, Hong Kong, Jul. 1999.

- [12] M. Bounadja, A. Mellakhi, B. Belmadani: A High Performance PWM Inverter Voltage-Fed Induction Machines Drive with an Alternative Strategy for Speed Control, *Serbian Journal of Electrical Engineering*, Vol. 4, No. 1, June 2007, 35 – 49.
- [13] M. Mazzucchelli and L. Puglisi, "PWM systems in power converters: an extension of the 'subharmonic method'", *IEEE Trans.on Industrial Electronics and Control Instrumentation*, vol. 28, no. 4, pp. 315-319, Nov. 1981.
- [14] T. J. Liang, R. M. O'Connell, and R. G. Hoft., "Inverter harmonic reduction using Walsh function harmonic elimination method," *IEEE Trans. on Power Electronics*, vol. 12, no. 6, pp. 971-982, Nov.1997.