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Phase Disposition and Phase opposition Disposition Carrier Based Hybrid Modulation Technique for Single Phase Five Level Inverter

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Abstract – Among the various types of multilevel inverters, cascaded multilevel inverter emerges to be better at high power rating because of its modular character of modulation, control and protection necessities of each H-bridge inverters. Cascaded Multilevel Inverter (CMLI) produces a medium voltage output derived from sequential connections of power cells that employs configurations of standard low-voltage components. This distinctive feature enables to obtain better quality output voltages and input currents with exceptional accessibility owing to their inherent component redundancy. In this paper, Hybrid Modulation Technique (HMT) has been proposed to examine the performance characteristics of Cascaded Five level Inverter.Many new modulation techniques for MLI topologies have been developed to provide an accurate sinusoid in steady state. The major challenges in modulation techniques used in MLI topologies are to provide high power quality and minimum switching frequency. This paper deals with the methodology to minimize the Total Harmonic Distortion (THD) generated in Multilevel Sinusoidal Pulse Width modulation (MSPWM) schemes with low computational involvedness. MATLAB-SIMULINK block set with logical elements is offered adopting sequential switching hybrid-modulation (SSHM) algorithm with PWM circulation. Even though only the five-level case is presented, the projected method can be equally applied to any number of voltage levels, any number of phases and switching transitions.

Keywords: - CMLI, Hybrid Modulation, Total Harmonic Distortion.

I INTRODUCTION

In recent years, the applications of multilevel inverters (MLIs) in industries for electronic power conversion of medium voltage and high-power have been on increase. This is because, enhancing the output waveform of the inverter decreases its relevant harmonic content resulting in reduced size of the filter and reduced level of Electro Magnetic Interference (EMI) generated during the switching operations. Among the various types of multilevel inverters, cascaded multilevel inverter emerges to be better at high power rating because of its modular character of modulation, control and protection necessities of each H-bridge inverters.

II HYBRID MODULATION

Fundamental Frequency Pulse Width Modulation (FFPWM) and Multiple Sinusoidal Pulse Width Modulation (MSPWM) are combined together resulting in Hybrid modulation. In hybrid modulation technique, the power devices of each inverter cells operate at two different frequencies, two being commutated at fundamental frequency, whereas the remaining two switches are modulated at MSPWM, therefore the resultant switching patterns are same as those obtained with MSPWM. A sequential switching scheme is introduced with this hybrid modulation in order to overcome unequal switching losses and differential heating among the power devices. Each switch is stressed in the same way to achieve equal losses in each switch and therefore a uniform temperature distribution within the inverter cell. A simple base MSPWM circulation scheme is also embedded to get resultant hybrid PWM circulation makes balanced power dissipation among the power modules.

III HYBRID PHASE DISPOSITION (PD) AND PHASE OPPOSITION DISPOSITION (POD) MODULATION

In Unipolar carrier-based N-level PWM operation, ($N - 1$)/2 different carriers, same as the number of FBI cells ($K = (N - 1)/2$) are present with same frequency f_c and the same peak-to-peak amplitude A_c. The MSPWM scheme using PD and POD is reviewed. The modulation index for MSPWM is calculated as $M = A_m / K A_c$.

The modulation frequency ratio is given as $MF = f_c / f_o$, where f_o is fundamental frequency and f_c is carrier frequency. In the phase-disposition method all triangular carriers are in phase as shown in Fig.1. In POD, the positive and negative carriers are in phase, but between them there is a phase shift of 180 degrees as shown in Fig.2.

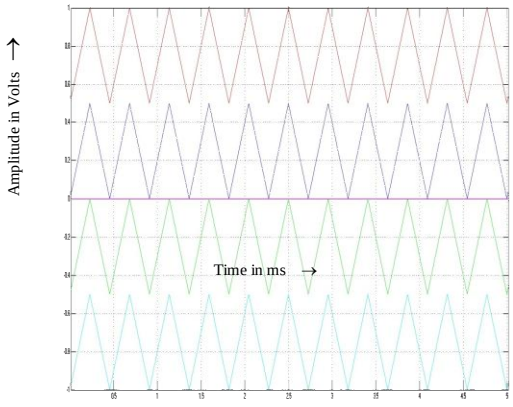

Figure 1 Sample Phase Disposition Carrier Signals

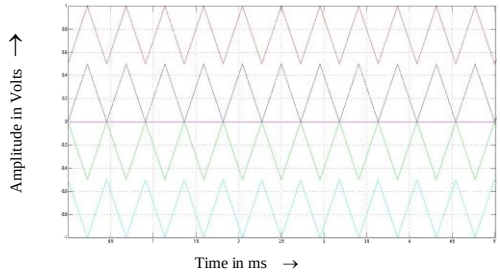

Figure 2 Sample Phase Opposition Disposition Carrier Signal

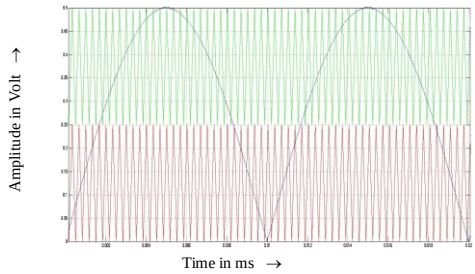

Figure 3 Sinusoidal Reference Signal with Triangular Carrier Signals

In this projected modulation strategy, FFPWM and PD and POD pulses are combined to produce HPD and HPOD pulses for each inverter cell. Fig. 3.4 shows the general structure of the projected sequential switching hybrid modulation method. It consists of base modulator, circulation module and Hybrid Modulation Controller (HMC) to generate new HPD and HPOD modulation pulses.

Symmetrical triangular carriers used in this modulation generate less harmonic distortion at the inverter's output. In the carrier set, the zero reference is always placed in the center. The modulating waveform V_m is a random waveform with the frequency f_o.

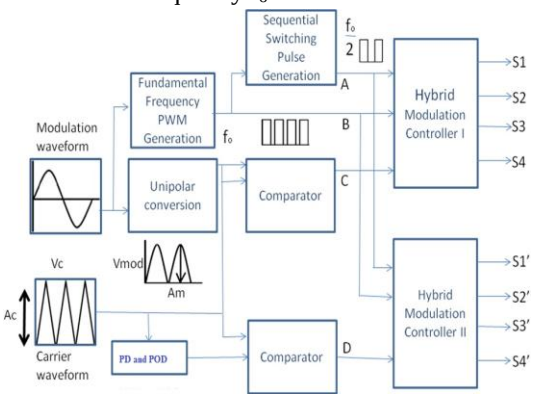

Figure 4 General Structure of Sequential Switching HPD and HPOD Modulation Scheme

PD and POD pulses for inverter cell-I (C) are obtained by the comparison of unipolar modulation waveform (V_{mod}) with carrier waveform (V_c). PD and POD pulses for inverter cell-II (D) are obtained by the comparison of same unipolar modulation waveform with level shifted carrier waveform ($-V_c + 2A_c$). The HMC combines the base PD and POD pulses and produce sequential switching HPD and HPOD pulses.

IV SEQUENTIAL SWITCHING HYBRID MODULATION

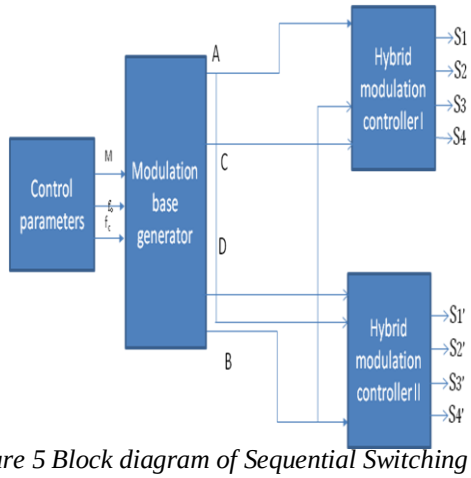

Figure 5 Block diagram of Sequential Switching Hybrid Modulation

The Fig.5 shows the sequential switching Hybrid Modulation for five level Cascaded Multilevel Inverter. The process of generating hybrid modulation pulses involves modulation base generator, base MSPWM circulation and hybrid modulation controllers. This modulation approach requires three base modulation pulses for each inverter cell in a CMI. For each inverter cell, the base modulation pulses required are Sequential Switching Pulse (SSP), FFPWM and MSPWM. A SSP (A) is a square wave signal having half the fundamental frequency with equal ON time and OFF time. This signal makes every power switch operating at MSPWM and FFPWM sequentially.

FFPWM (B) is a square wave signal synchronized with the modulation waveform; it is active high during the positive half cycle of the modulation signal, and active low during negative half cycle shown in Fig.3.4. In each phase, SSP and FFPWM pulses are identical for all inverter cells. MSPWM (C and D) for each inverter cell depends upon the type of well-known PD and POD pulses used. The control parameters are modulation index (M), carrier frequency (f_c), and fundamental frequency (f_o).

V HYBRID MODULATION CONTROLLER

Hybrid Modulation Controller (HMC) generates hybrid modulation pulses which are combination of SSP, FFPWM and MSPWM. For HMC the corresponding input pulses are SSP (A), FFPWM (B), and MSPWM (C' and D') respectively. The number of independent HMC increases with the increase in level of Inverter Bridge. The implementation of hybrid PWM controller is achieved by using simple combinational logic which further eases the processing. The combinational logic for a five-level hybrid PWM operation are expressed as

$$S_1 = ABC' + \bar{A}\,B \quad S_1' = ABD' + \bar{A}\,B$$
$$S_2 = \bar{A}\bar{B}C' + \bar{A}\bar{B} \quad S_2' = \bar{A}\bar{B}D' + \bar{A}\bar{B}$$
$$S_3 = \bar{A}\bar{B}C' + A\bar{B} \quad S_3' = \bar{A}\bar{B}D' + A\bar{B}$$
$$S_4 = \bar{A}\bar{B}C' + AB \quad S'_4 = \bar{A}\bar{B}D' + AB \qquad (1)$$

Fig.6 shows the functional logic diagram of five-level hybrid modulation controller. To combine SSP, FFPWM and its consequent MSPWM for obtaining hybrid modulation pulses in K^{th} inverter cell, an independent HMC is utilized. FFPWM pulses, PD and POD pulses are present in the input gate pulse. When SSP A=1, then S1, S2, S1' and S2' are activated with PD or POD, while S3, S4, S3', S4' are activated with FFPWM. When SSP A=0, then S1, S2, S1' and S2' are activated at FFPWM, while S3, S4, S3' and S4' are activated with PD or POD. Since A is a sequential signal, the average switching frequency amongst the four power devices in each inverter cell is equalized.

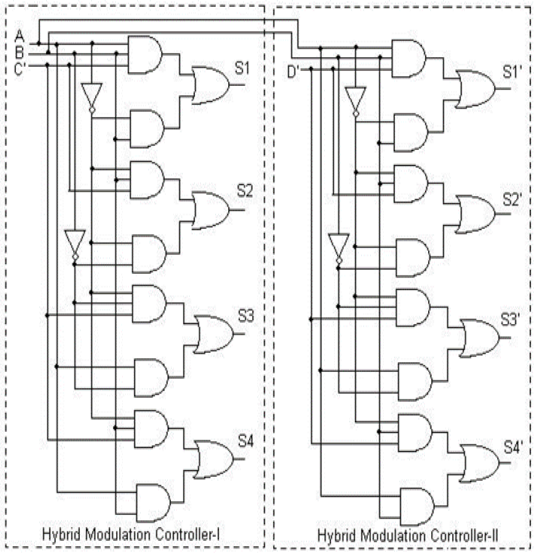

Figure 6 Functional Logic Diagram of Five Level Hybrid Modulation Controller

With this modulation, voltage stress and current stress of power switches is also naturally equalized. For every two fundamental frequency cycles, the SSHSM pulse pattern is altered so that the first module (S_1, S_2, S_3, and S_4) turns into the second module (S_1', S_2', S_3', and S_4'), and the second one turns into the first. It can be observed from Fig. 3.8 that the Vh1 and Vh2 are operating at same average switching frequency with the same conduction period.

VI SIMULATION RESULTS OF HYBRID PHASE DISPOSITION CARRIER BASED FIVE LEVEL CASCADED MULTILEVEL INVERTER

Hybrid Phase Disposition (HPD) modulation is developed and implemented using MATLAB simulink block set. Corresponding simulation results are presented and analyzed. In the simulink model, the DC-bus voltage is set at 100 V, the modulated wave frequency is 50 Hz and carrier wave frequency is 1500 Hz. The load resistance is chosen as 100 Ω. Hybrid PWM controlled five level inverter fed motor is also simulated in MATLAB simulink block set. Fig.7 shows the simulated switching pulses of HPD five level CMLI. Fig.8 shows the simulated output voltage of each H-bridge, output voltage V_o of the inverter and the output current I_o with resistive load 100 Ω. Fig.9 shows the THD of hybrid modulated multicarrier PD controlled cascaded five level inverter output voltage with resistive load 100 Ω. Fig.10 shows the speed of hybrid modulated multi carrier PD switched five level inverter controlled single phase induction motor. Fig 11 – Fig.12 shows the output voltage of hybrid modulated multi carrier PD controlled five level inverter with motor load and its corresponding %THD respectively.

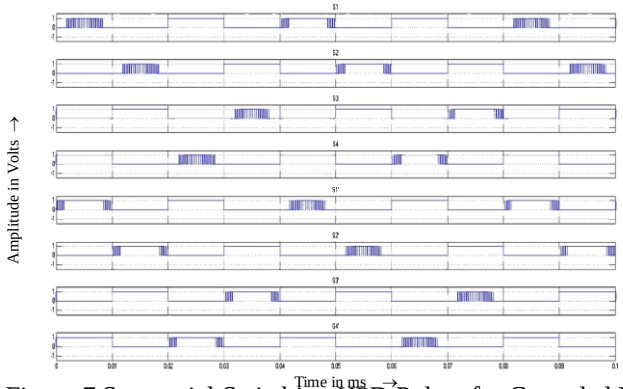

Figure 7 Sequential Switching HPD Pulses for Cascaded Five Level Inverter

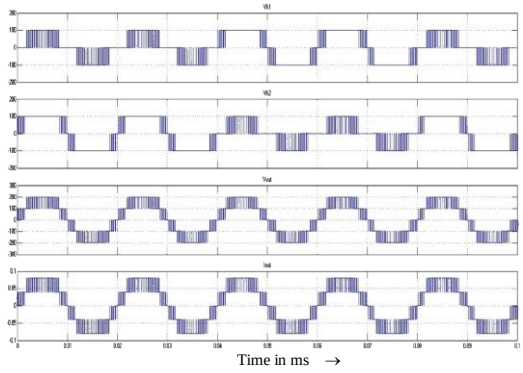

Figure 8 H- Bridge Output Voltage Vh_1, Vh_2, Output Voltage (V_o) and Output Current (I_o) of Hybrid Modulated Multi Carrier PD Controlled Cascaded Five Level Inverter with 100 Ω Resistive Load

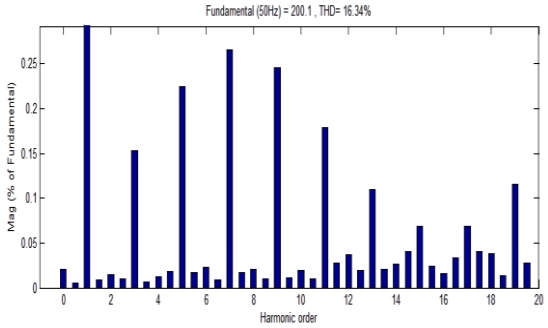

Figure 9 % THD of Hybrid Modulated Multi Carrie

PD Controlled Cascaded Five Level Inverter Output Voltage with 100 Ω Resistive Load

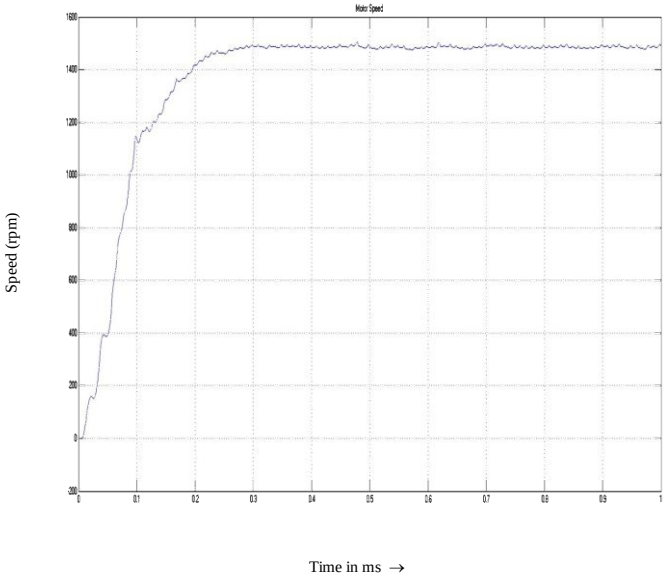

Figure 10 Speed of Hybrid Modulated Multi Carrier PD Switched Five Level Inverter Controlled Single Phase Induction Motor

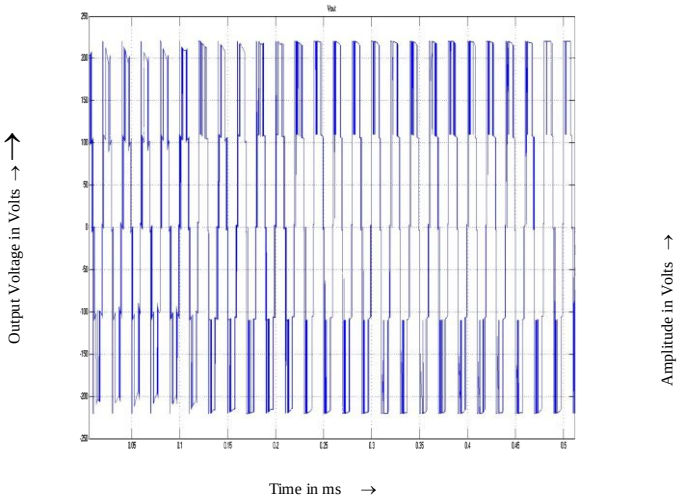

Figure 11 Output Voltage of Hybrid Modulated Multi Carrier PD Controlled Five Level Inverter with Motor Load

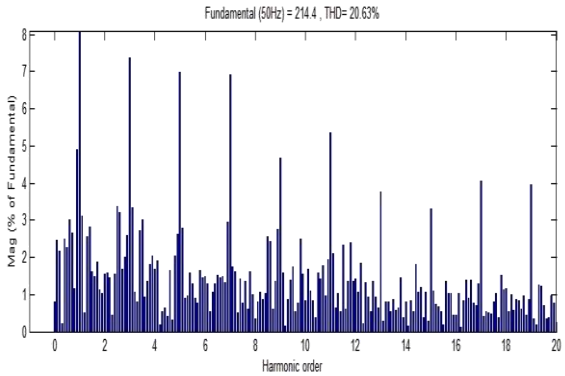

Fig.12 % THD of Hybrid Modulated Multi Carrier PD Controlled Cascaded Five Level Inverter Output Voltage with Motor Load

VII SIMULATION RESULTS OF HYBRID PHASE OPPOSITION DISPOSITION CARRIER BASED FIVE LEVEL CASCADED MULTILEVEL INVERTER

Hybrid Phase Opposition Disposition (HPOD) modulation is developed and implemented using MATLAB simulink block set. Corresponding simulation results are presented and analyzed. In the simulink model, the DC-bus voltage is set at 100 V, the modulated wave frequency is 50 Hz and carrier wave frequency is 1500 Hz. The load resistance is chosen as 100 Ω. Hybrid PWM controlled five level inverter fed motor is also simulated in MATLAB simulink block set. Fig.13 shows the simulated switching pulses of HPOD five level CMLI. Fig.14 shows the simulated output voltage of each H-bridge, output voltage V_o of the five level inverter and the output current I_o with resistive load 100 Ω. Fig.15 shows the %THD of hybrid modulated multi carrier POD controlled cascaded five level inverter output voltage with resistive load 100 Ω. Fig.16 shows the speed of hybrid modulated multi carrier POD switched five level inverter controlled single phase induction motor.

Fig.17 –Fig.18 shows the output voltage of hybrid modulated multi carrier POD controlled five level inverter with motor load and its corresponding %THD respectively.

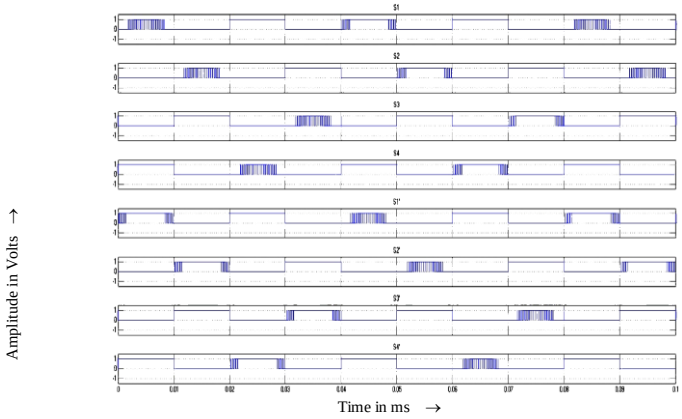

Figure 13 Sequential Switching HPOD Pulses for Cascaded Five Level Inverter

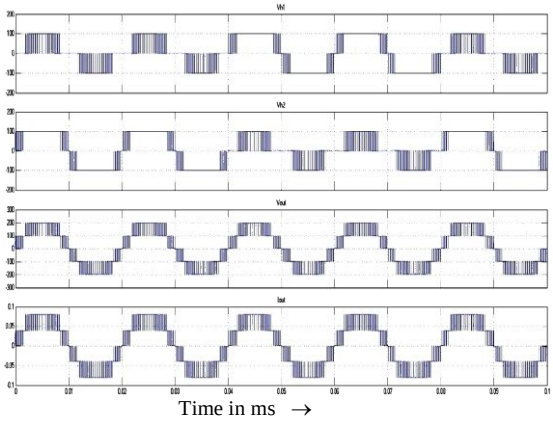

Figure 14 H- Bridge Output Voltage Vh_1, Vh_2, Output Voltage (V_o) and Output Current (I_o) of Hybrid Modulated Multi

Carrier POD Controlled Five Level Inverter with Resistive 100 Ω Load

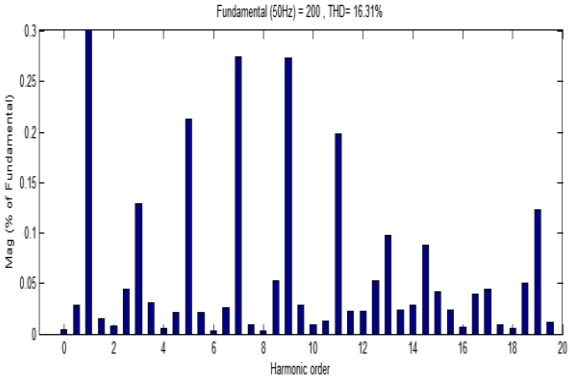

Figure 15 % THD of Hybrid Modulated Multi Carrier POD Controlled Cascaded Five Level Inverter Output Voltage with Resistive 100 Ω Load

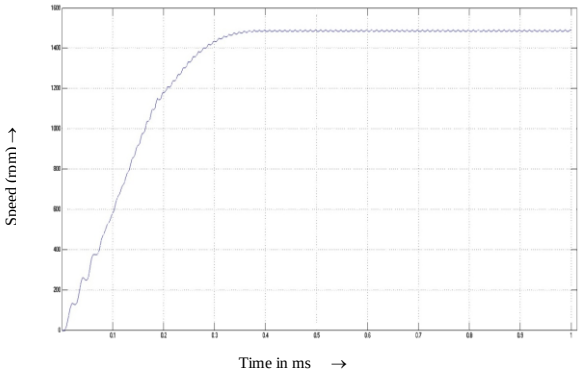

Figure 16 Speed of Hybrid Modulated Multi Carrier POD Switched Five Level Inverter Controlled Single Phase Induction Motor

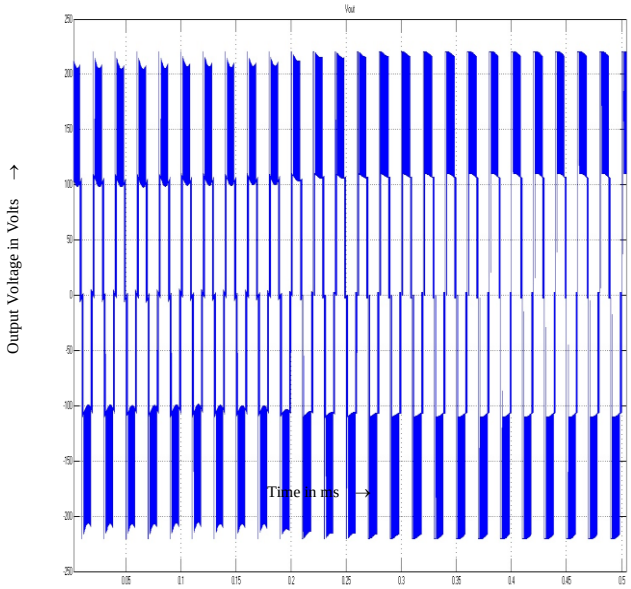

Figure 17 Output Voltage of Hybrid Modulated Multi Carrier POD Controlled Five Level Inverter with Motor Load

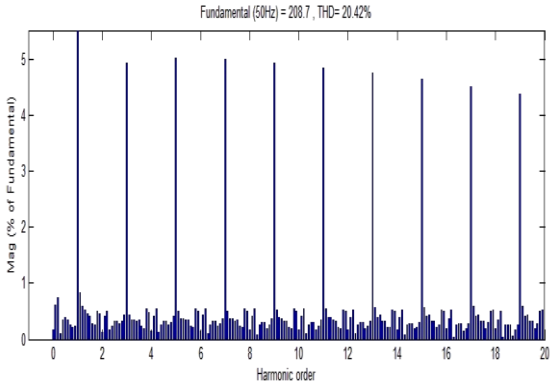

Fig.18 % THD of Hybrid Modulated Multi Carrier POD Controlled Cascaded Five Level Inverter Output Voltage with Motor Load

VIII CONCLUSION

Hybrid modulation is developed by combining fundamental frequency pulse width modulation and multiple sinusoidal pulse width modulation to control the chosen five level inverter. Switching pulses are generated by comparing the phase disposition and phase opposition disposition multicarrier with unipolar sinusoidal reference wave. The generated switching pulses are fed to the chosen five level inverters with resistive load and motor load. From the simulation results, it has been observed that the realization of HPWM circulation enables the inverter modules to function at similar average switching frequency with identical conduction period. The %THD of Hybrid Modulated Multi Carrier PD and POD Controlled Cascaded Five Level Inverter Output Voltage with Resistive load is 16.34 and 16.31 respectively. The %THD of Hybrid Modulated Multi Carrier PD and POD Controlled Cascaded Five Level Inverter Output Voltage with motor load is 20.63 and 20.42 respectively. The THD level in the output voltage of HPOD modulation technique controlled five level inverter is less compared to HPD modulation technique with both resistive and motor load.

REFERENCES

[1] A. Nabae, I. Takahashi, and H. Akagi, "A new neutralpoint-clamped PWM inverter," IEEE Trans. Ind. Appl., Sep./Oct. 1981,vol. 17(5), pp. 518–523,.

[2] M. Marchesoni and M. Mazzucchelli, "Multilevel converters for high power AC drives: a review," in Proc. IEEEISIE'93, Budapest, Hungary,1993, pp. 38– 43

[3] J. S. Lai and F. Z. Peng, ''Multilevel Converters- A New Breed of Power Converters," IEEE Transaction on Ind.Applicat., May/June 1996. vo32, pp. 509 – 517,

[4] Malinowski, M., Gopakumar, K., Rodriguez, J., Pérez, M.A : "A survey on cascaded multilevel inverters", IEEE Trans. Ind. Electron., 2010, 57(7), pp. 2197–2206 .

[5] Du, Z., Tolbert, L.M., Ozpineci, B. and Chiasson, J.N.,Fundamental Frequency Switching Strategies Of A Seven-Level Hybrid Cascaded H-Bridge Multilevel Inverter, IEEE Transactions on Power Electronics, 2009,Vol.24(1),pp.25-33.

[6] Balamurugan, C.R., Natarajan, S.P. and Bensraj, R. "Comparative Study on Various Bipolar Hybrid Carrier PWM Strategies for Three Phase Five Level Cascaded Inverter", IEEE International Conference on Power and Computing Technologies, Nagercoil, March 2013, 269-274.

[7] C. Govindaraju ,K. Baskaran "Efficient Sequential Switching Hybrid-Modulation Techniques for Cascaded Multilevel Inverters", IEEE Transactions on Power Electronics, 2011 26(6).

[8] Farid Khoucha, Soumia Mouna Lagoun, Khoudir Marouani, Abdelaziz Kheloui, and Mohamed El Hachemi Benbouzid, "Hybrid Cascaded Hbridge Multilevel-Inverter Induction-Motor-Drive Direct Torque Control for Automotive Applications" , IEEE Trans. on Industrial Electronics, 2010, Vol. 57(3), pp. 892-899.

[9] Jordi Zaragoza , Josep Pou ,Eider Robles , Pedro Ibanez and Jose Luis Villate "A Comprehensive Study of a Hybrid Modulation Technique for the Neutral-Point-Clamped Converter", IEEE Trans. on Industrial Electronics, 2009, Vol. 56(2), pp. 294-304.

[10] C. Rech and J. R. Pinheiro, "Hybrid multilevel converters: Unified analysis and design considerations," IEEE Trans. Ind. Electron., 2007 vol. 54(2), pp. 1092–1104.

[11] C. Govindaraju1 and K. Baskaran, "Sequential Switching Hybrid Single-carrier Sinusoidal Modulation for Cascaded Multi-level Inverter," Electric Power Components and Systems, 2011, 39(4), pp.303- 316.