# Carrier-based modulation for NPC inverter in dual-inverter supply configuration

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**ABSTRACT:** Dual-inverter supply drives enable the realization of Neutral Point Clamped (NPC) multilevel inverter without the need of complex capacitor voltage balancing algorithm and complicated semiconductors switching control. This paper presents carrier-based modulation techniques (level shifted and phase shifted PWM) for NPC inverter which realized in dual-inverter supply configuration. Simulation works carried out using Matlab/Simulink shows that multilevel output voltage is produced and phase disposition PWM (PD-PWM) produces the lowest voltage harmonic distortion among the applied carrier-based modulation techniques.

**Keywords:** *multilevel inverter; dual-inverter supply drives; carrier-based modulation*

## 1. INTRODUCTION

Multilevel inverters are widely used for medium and high power industrial applications due to its advantages to provide higher power capability with voltage-limited devices, lower harmonic distortion, reduced switching losses, and increased efficiency as compared to two-level inverter [1-2]. Besides the traditional configuration of multilevel inverter, the implementation of multilevel inverter can also be realized by using dual-inverter supply configuration such as shown in Figure 1 [3]. For this multilevel drives configuration, two inverters are required to supply both ends of the load as compared to traditional multilevel inverter that supply the star connected load using single multilevel inverters.

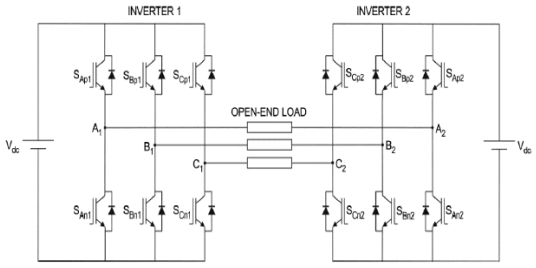


Figure 1 Multilevel inverters with dual-inverter supply configuration

Multilevel inverters with dual-inverter supply configuration offer several advantages, as compared to the traditional topology. First, the multilevel output voltage can be achieved by using two two-level inverters, which avoid the usage of capacitor voltage balancing algorithm required by traditional multilevel inverters. Second, if batteries are used as the sources for the two inverters, for example in electric vehicles application, the topology requires less semiconductors than the three-level inverter in single-sided supply mode. Finally, fault tolerance of the drives could also be increased, since, if one of the inverters is inoperable, the drives can be reconfigured to be driven by a single inverter to continually operate at a reduced power output.

This paper presents the implementation of NPC inverter via dual-inverter supply configuration. The inverter is controlled by carrier based modulation strategy based on level shifted PWM (LS-PWM) and phase shifted PWM (PS-PWM). For LS-PWM, only Phase Disposition (PD-PWM) and alternate phase opposition disposition (APOD-PWM) are implemented because for three level operation, phase opposition disposition (POD-PWM) behave similarly as APOD-PWM. The implementation of these modulation methods are explained in the next section.

## 2. MODULATION STRATERGY

In the dual-inverter supply topology, both inverters need to be controlled separately using two sets of modulating and carrier signals so that the voltage supplied to the open-end load are the net voltage supplied by these two inverters. For implementation of LS-PWM and PS-PWM, the arrangement of carrier and modulating signals for both inverters are as shown in Figure 2.

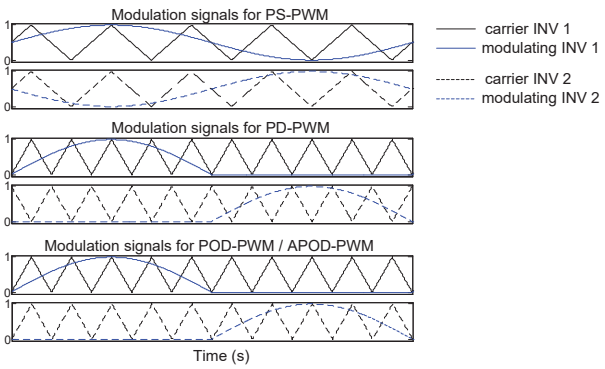


Figure 2 Arrangement of carrier and modulating signals for modulation of dual-inverter supply topology

The implementation of dual-inverter supply NPC inverter with open-end *R-L* load is simulated using Matlab/Simulink shown in Figure 3. DC supply for each inverter is set to 100V and modulating signal frequency is set at 50Hz. Carrier signal frequency for PSPWM is set to 2.5kHz while for PDPWM and APODPWM is set to 5kHz so that all the modulation methods operate at the same average switching frequency.

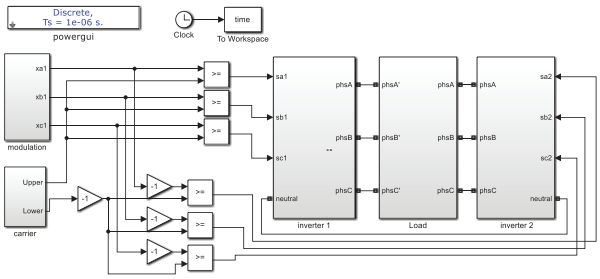


Figure 3 Simulation of NPC inverters with dual inverter supply configuration using Matlab/Simulink

## 3. RESULTS AND DISCUSSION

The phase voltage and line-line voltage waveforms for each modulation method with modulation index $m_a$ = 1 are shown in Figure 4 and 5. From the figures it can be seen that multilevel operation is obtained as the phase voltage are alternates between 0 and $\pm V_{dc}$ while the line-line voltage alternates between 0, $\pm V_{dc}$ and 0 and $\pm 2V_{dc}$.

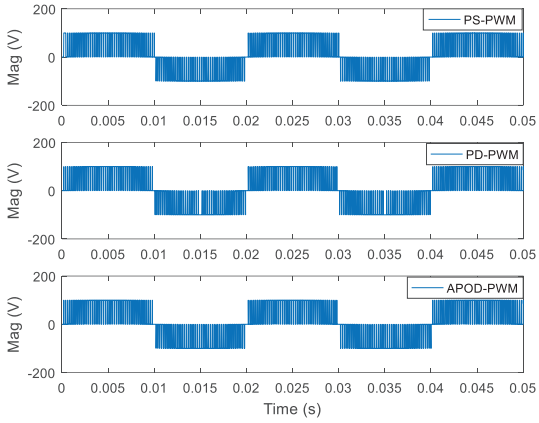


Figure 4 Phase voltage waveforms for PS-PWM (top), PD-PWM (middle) and APOD-PWM (bottom).

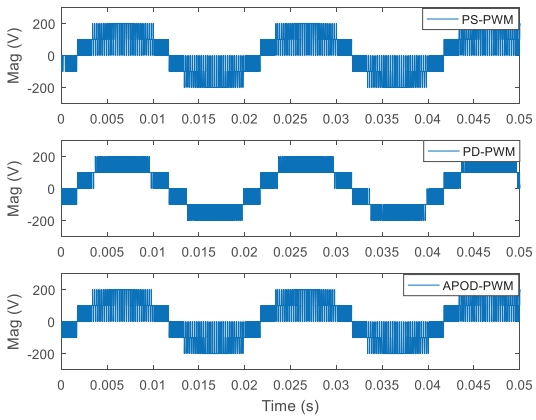


Figure 5 Line-line voltage waveforms for PS-PWM (top), PD-PWM (middle) and APOD-PWM (bottom).

From Figure 5 also, it can be observed that PS-PWM and APOD-PWM produce a quasi-multilevel line-line voltage whereas the voltage alternates between zero and positive/negative values while for PD-PWM, a normal multilevel output is obtained. As a result, PD-PWM produces the lowest voltage THDs among the three modulation methods while PS-PWM and APOD-PWM produce similar harmonics characteristics. Comparison of line-line voltage THD produced by each modulation method for the full linear range of modulation index, spanning from $m_a$ = 0.1 to $m_a$ =1 with 0.1 increments is shown in Figure 6.

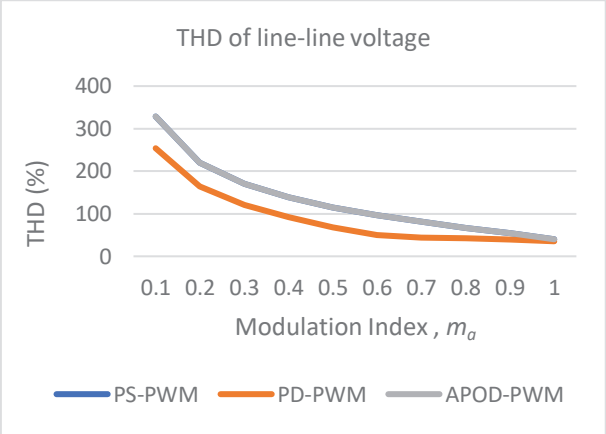


Figure 6 Performance of PS-PWM, PD-PWM and APOD-PWM (THD vs $m_a$)

## 4. CONCLUSION

This paper presents carrier-based modulation methods for NPC inverter in dual-inverter supply configuration modulated using carrier-based modulation methods (level shifted and phase shifted PWM). Based on simulation results, PD-PWM produces the lowest voltage THD with a multilevel output voltage as compared to quasi-multilevel voltage produced by PS-PWM and APOD-PWM.

## ACKNOWLEDGEMENT

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