VOLTAGE CONTROL OF INVERTERS

Note Title 1/7/2015

VOLTAGE CONTROL OF SINGLE-PHASE INVERTERS

Single-Pulse-Width Modulation

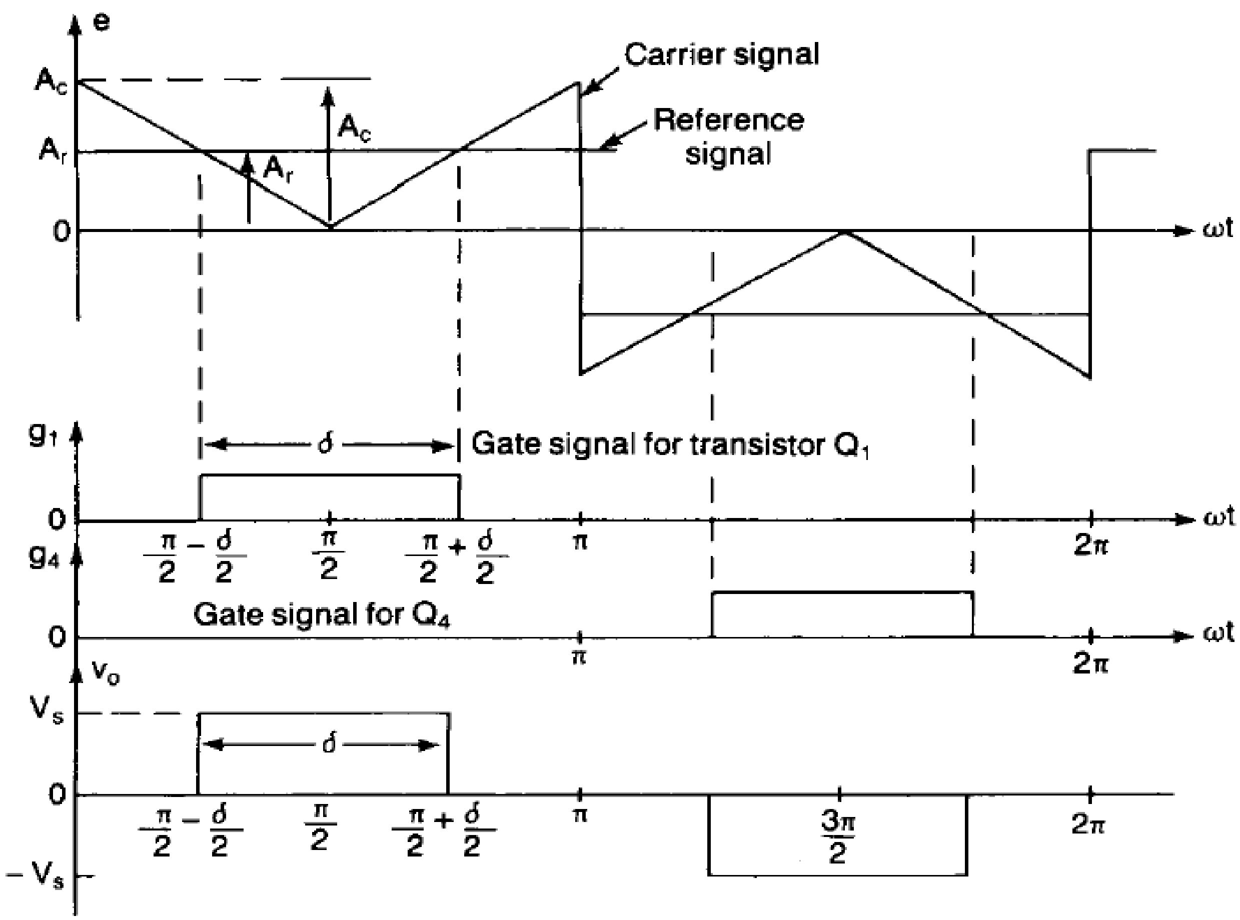


Figure 8-9 Single-pulse-width modulation.

The modulation index,

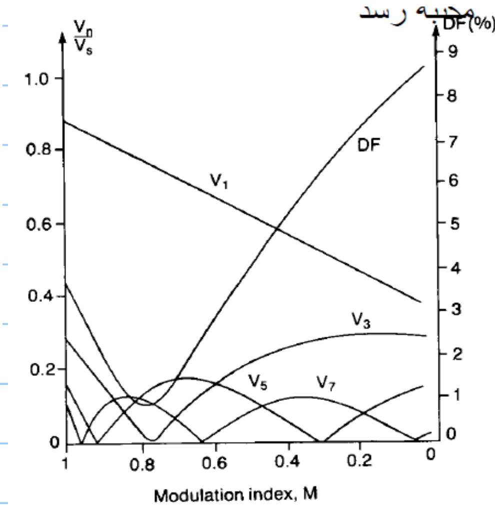
$$M = \frac{A_r}{A_c}$$

The rms output voltage can be found from

$$V_o = \left[\frac{2}{2\pi}\int_{(\pi-\delta)/2}^{(\pi+\delta)/2} V_s^2 \, d(\omega t)\right]^{1/2} = V_s\sqrt{\frac{\delta}{\pi}}$$

The Fourier series of output voltage yields

$$v_o(t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_s}{n\pi}\sin\frac{n\delta}{2}\sin n\omega t$$



Multiple-Pulse-Width Modulation

uniform pulse-width modulation (UPWM)

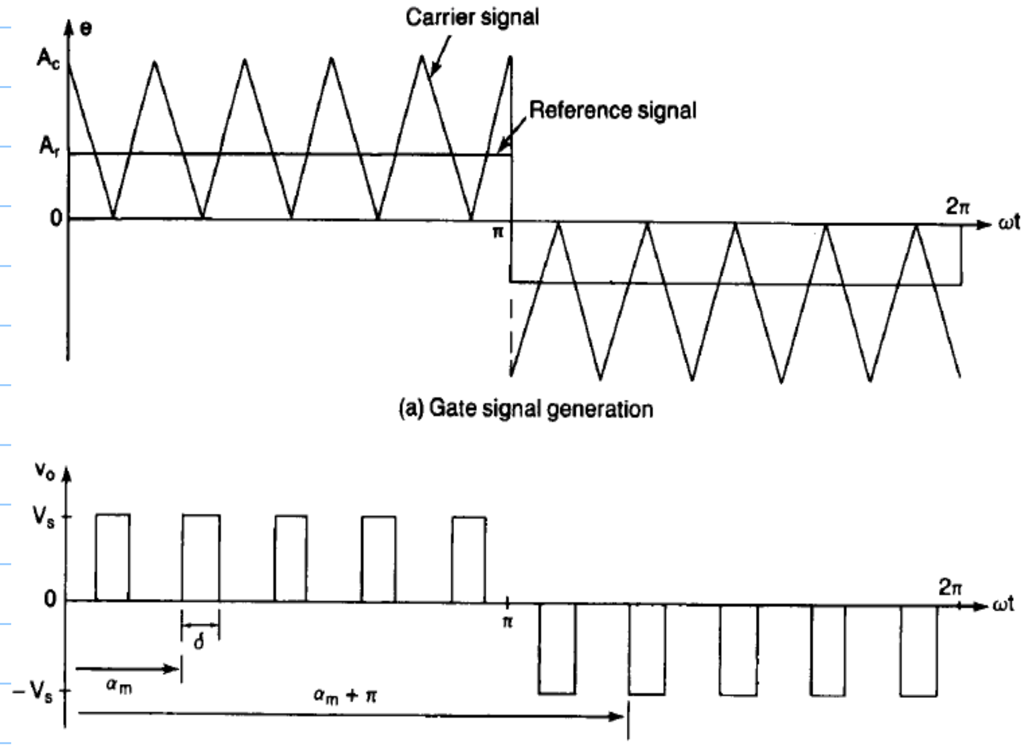


Figure 8-11 Multiple-pulse-width modulation.

The number of pulses per half-cycle is found from

$$N = \frac{f_c}{2f_o}$$

If δ is the width of each pulse, the rms output voltage can be found from

$$V_o = \left[\frac{2p}{2\pi}\int_{(\pi/p-\delta)/2}^{(\pi/p+\delta)/2} V_s^2 \, d(\omega t)\right]^{1/2} = V_s\sqrt{\frac{p\delta}{\pi}} \tag{8-21}$$

The general form of a Fourier series for the instantaneous output voltage is

$$v_o(t) = \sum_{n=1,3,5,\ldots}^{\infty} (A_n \cos n\omega t + B_n \sin n\omega t)$$

If the positive pulse of mth pair starts at $\omega t = \alpha_m$ and ends at $\omega t = \alpha_m + \pi$, the Fourier coefficients for a pair of pulses are

$$a_n = \frac{2V_s}{\pi}\int_{\alpha_m}^{\alpha_m+\delta} \cos n\omega t \, d(\omega t) = \frac{2V_s}{n\pi}[\sin n(\alpha_m + \delta) - \sin n\alpha_m]$$

$$= \frac{4V_s}{n\pi}\sin\frac{n\delta}{2}\cos n\left(\alpha_m + \frac{\delta}{2}\right) \tag{8-23}$$

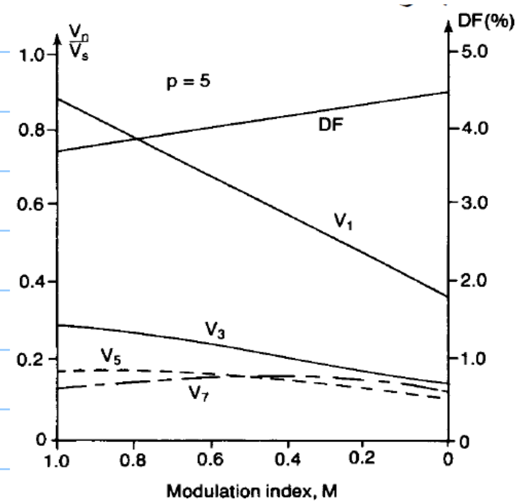
$$b_n = \frac{2V_s}{\pi}\int_{\alpha_m}^{\alpha_m+\delta} \sin n\omega t \, d(\omega t) = \frac{2V_s}{n\pi}[\cos n\alpha_m - \cos n(\alpha_m + \delta)]$$

$$= \frac{4V_s}{n\pi}\sin\frac{n\delta}{2}\sin n\left(\alpha_m + \frac{\delta}{2}\right) \tag{8-24}$$

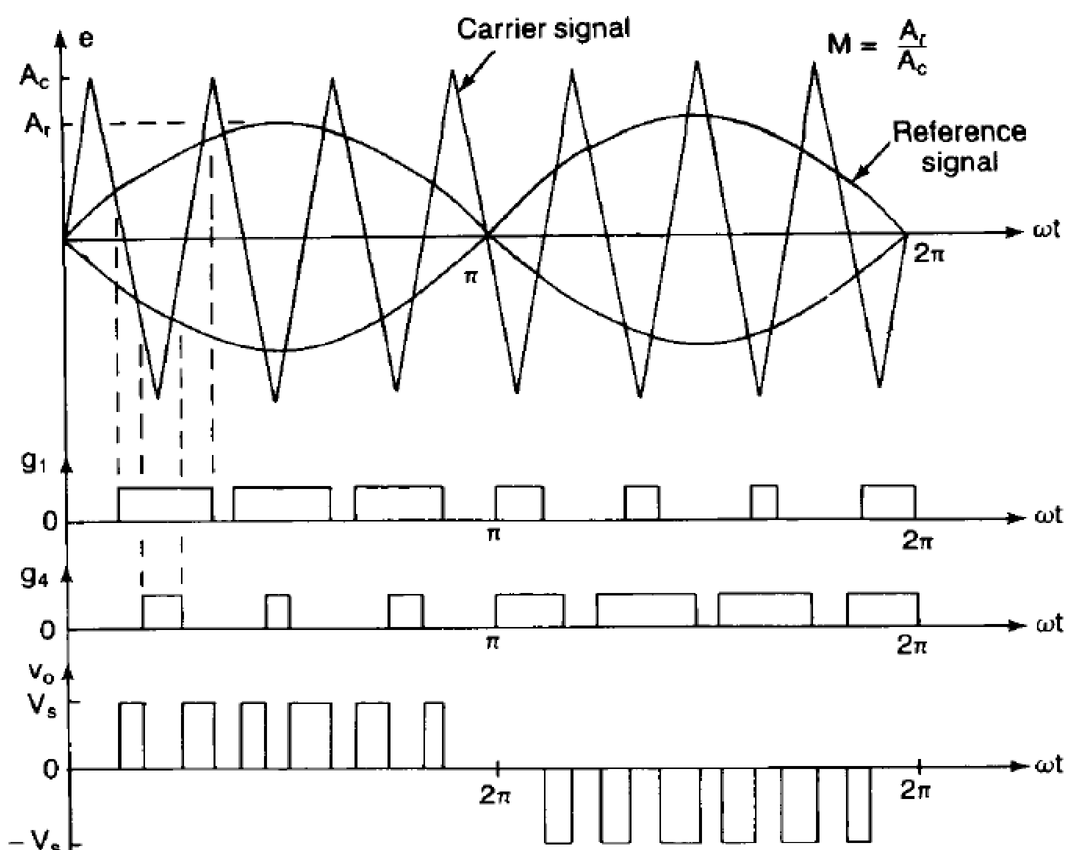
The coefficients of Eq. (8-22) can be found by adding the effects of all pulses,

$$A_n = \sum_{m=1}^{p} \frac{4V_s}{n\pi} \sin \frac{n\delta}{2} \cos n\left(\alpha_m + \frac{\delta}{2}\right) \tag{8-25}$$

$$B_n = \sum_{m=1}^{p} \frac{4V_s}{n\pi} \sin \frac{n\delta}{2} \sin n\left(\alpha_m + \frac{\delta}{2}\right) \tag{8-26}$$



Sinusoidal Pulse-Width Modulation



(a)

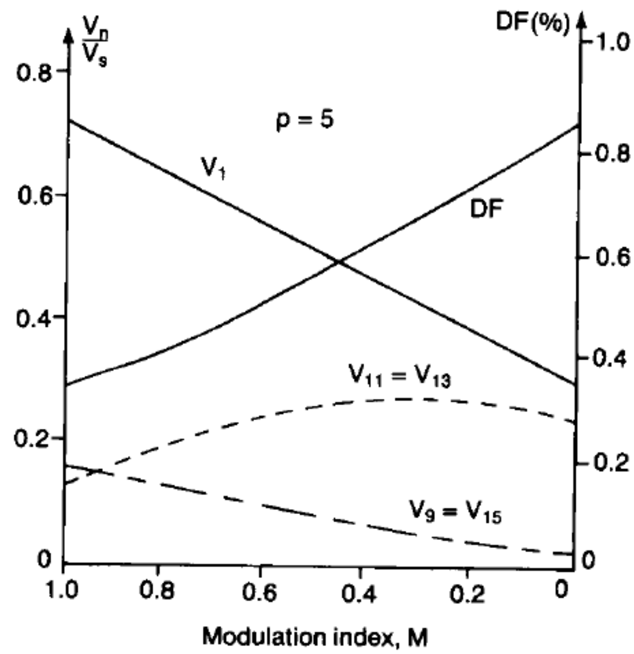
If δ_m is the width of mth pulse, Eq. (8-21) can be extended to find the rms output voltage

$$V_o = V_s \left(\sum_{m=1}^{p} \frac{\delta_m}{\pi} \right)^{1/2}$$

$$A_n = \sum_{m=1}^{p} \frac{2V_s}{n\pi} [\sin n(\alpha_m + \delta_m) - \sin n\alpha_m]$$

$$B_n = \sum_{m=1}^{p} \frac{2V_s}{n\pi} [\cos n\alpha_m - \cos n(\alpha_m + \delta_m)]$$

all harmonics less than or equal to $2p - 1 = 0$



VOLTAGE CONTROL OF THREE-PHASE INVERTERS

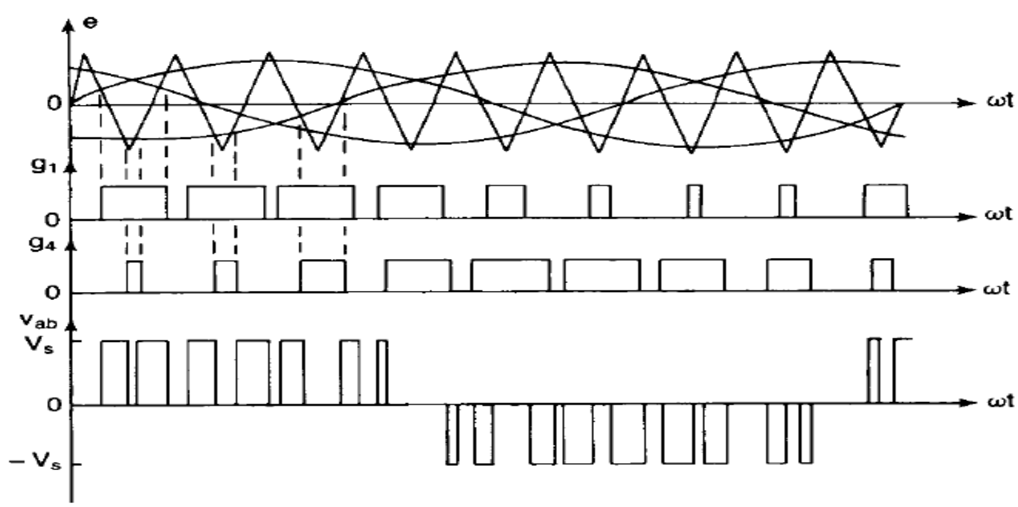


Figure 8-17 Sinusoidal pulse width modulation for three-phase inverter.

Example 8-1

A single-phase half-bridge inverter in Fig. 8-1a has a resistive load of $R = 2.4\ \Omega$ and the dc input voltage is $V_s = 48$ V. Determine the (a) rms output voltage at the fundamental frequency, V_1; (b) output power, P_o; (c) average and peak currents of each transistor; (d) peak reverse blocking voltage of each transistor, V_B; (e) total harmonic distortion, THD; (f) distortion factor, DF; and (g) harmonic factor and distortion factor of the lowest-order harmonic.

Solution $V_s = 48$ V and $R = 2.4\ \Omega$.

(a) From Eq. (8-3), $V_1 = 0.45 \times 48 = 21.6$ V.

(b) From Eq. (8-1), $V_o = V_s/2 = 48/2 = 24$ V. The output power, $P_o = V_o^2/R = 24^2/2.4 = 240$ W.

(c) The peak transistor current, $I_p = 24/2.4 = 10$ A. Since each transistor conducts for a 50% duty cycle, the average current of each transistor is $I_D = 0.5 \times 10 = 5$ A.

(d) The peak reverse blocking voltage, $V_B = 2 \times 24 = 48$ V.

(e) From Eq. (8-3), $V_1 = 0.45V_s$ and

$$\left(\sum_{n=3,5,7,\ldots}^{\infty} V_n^2\right)^{1/2} = (V_0^2 - V_1^2)^{1/2} = 0.2176V_s$$

From Eq. (8-5), THD $= 0.2176V_s/(0.45V_s) = 48.34\%$.

(f) From Eq. (8-2),

$$\left[\sum_{n=3,5,\ldots}^{\infty}\left(\frac{V_n}{n^2}\right)^2\right]^{1/2} = \left[\left(\frac{V_3}{3}\right)^2 + \left(\frac{V_5}{5}\right)^2 + \left(\frac{V_7}{7}\right)^2 + \cdots\right]^{1/2} = 0.01712V_s$$

From Eq. (8-6), DF $= 0.01712V_s/(0.45V_s) = 3.804\%$.

(g) The lowest-order harmonic is the third, $V_3 = V_1/3$. From Eq. (8-4), $HF_3 = V_3/V_1 = 1/3 = 33.33\%$, and from Eq. (8-7), $DF_3 = (V_3/3^2)/V_1 = 1/27 = 3.704\%$.

Example 8-5

A single-phase full-bridge inverter controls the power in a resistive load. The nominal value of input dc voltage is $V_s = 220$ V and a uniform pulse-width modulation with five pulses per half-cycle is used. For the required control, the width of each pulse is 30°. (a) Determine the rms voltage of the load. (b) If the dc supply increases by 10%, determine the pulse width to maintain the same load power. (c) If the maximum possible pulse width is 35°, determine the minimum allowable limit of the dc input source.

Solution (a) $V_s = 220$ V, $p = 5$, and $\delta = 30°$. From Eq. (8-21), $V_o = 220\sqrt{5 \times 30/180} = 200.8$ V.

(b) $V_s = 1.1 \times 220 = 242$ V. Using Eq. (8-21), $242\sqrt{5\delta/180} = 200.8$ and this gives the required value of pulse width, $\delta = 24.75°$.

(c) To maintain the output voltage of 200.8 at the maximum possible pulse width of $\delta = 35°$, the input voltage can be found from $200.8 = V_s\sqrt{5 \times 35/180}$, and this yields the minimum allowable input voltage, $V_s = 203.64$ V.