Concordia University Department of Electrical and Computer Engineering

ELEC-331

Lecture 14

Inverter circuits

Power electronics (from N. Mohan)

General considerations

- Produce an ac waveform from a dc bus.
- Basic applications: Ac motor drives and uninterruptible power supplies (UPS).

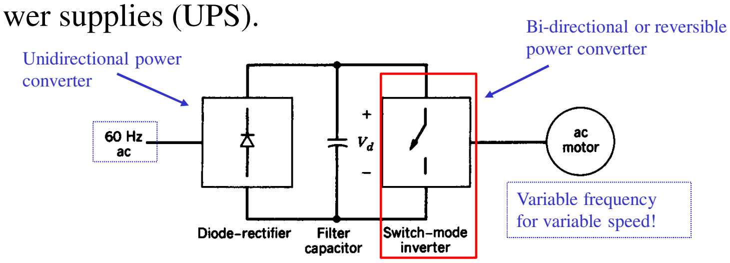


Figure 8-1 Switch-mode inverter in ac motor drive.

- Only single-phase inverters are discussed in this course.

Half-bridge inverter with square-wave output

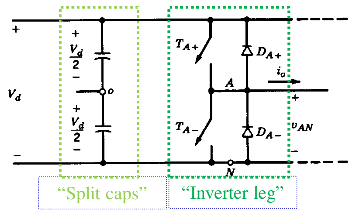


Figure 8-4 One-leg switch-mode inverter.

V_{Ao} is either $V_d/2$ (T_{A+} ON) V or $-V_d/2$ (T_{A-} ON).

V_{AN} is either 0 or V_d volts.

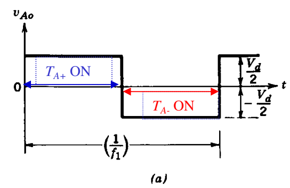


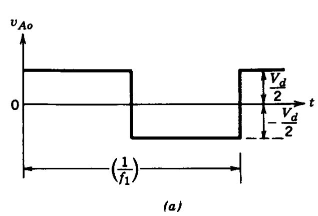
Figure 8-9 Square-wave switching.

- Operating principles:
- Each switch from a *leg* is on for half a cycle (180°) of the desired fundamental output frequency. Complementary operation.
- Diodes are required for inductive loads.

Square-wave switching scheme

- Each switch from a leg is on for half a cycle (180°) of the de sired fundamental output frequency.
- Disadvantages: 1) The inverter cannot control the magnitude of the fundamental; 2) Presents low order odd harmonics.

$$(\hat{V}_{Ao})_1 = \frac{4}{\pi}\frac{V_d}{2} = 1.273\left(\frac{V_d}{2}\right) \qquad (\hat{V}_{Ao})_h = \frac{(\hat{V}_{Ao})_1}{h}, h \text{ odd integer}$$



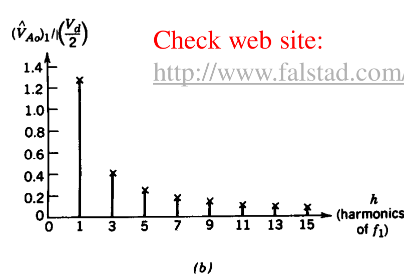
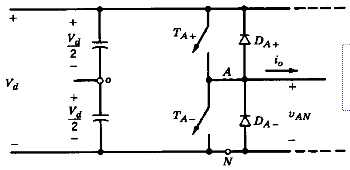


Figure 8-9 Square-wave switching.

Check web site: http://www.falstad.com/fourier/

Not appropriate for motor speed control!

Half-Bridge SPWM inverter

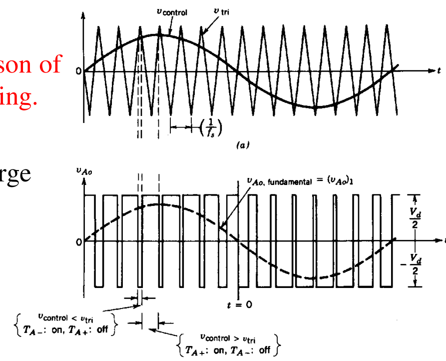


V_{Ao} is either $-V_d/2$ or $V_d/2$ volts.

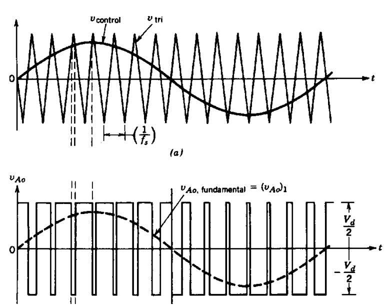
V_{AN} is either 0 or V_d volts.

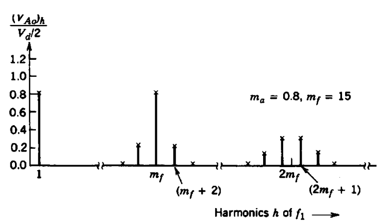
Figure 8-4 One-leg switch-mode inverter.

- **<u>Sinusoidal PWM (SPWM)</u>**
- Gate signal generation: Comparison of triangular carrier & sine modulating.
- Important indices:
- <u>Frequency modulation ratio</u> (a large odd integer) $m_f = \dfrac{f_{tri}}{f_{control}}$
- <u>Amplitude modulation ratio</u> $m_a = \dfrac{\hat{V}_{control}}{\hat{V}_{tri}}$



Characteristics of the output voltage





- Same fundamental frequency (f_1) and phase of the modulating signal ($v_{control}$)
- "Magnitude" of the fundamental (f_1) is: $(\hat{V}_{Ao})_1 = m_a \dfrac{V_d}{2}, \quad m_a = \dfrac{\hat{V}_{control}}{\hat{V}_{tri}} \le 1$
- Voltage harmonics appear at sidebands of multiples of the switching frequency (f_{tri})

$$f_h = (j\,m_f \pm k) f_1, \quad j \text{ integer } k \text{ odd/even}$$

$$h = j\,m_f \pm k$$

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Full-bridge inverter scheme

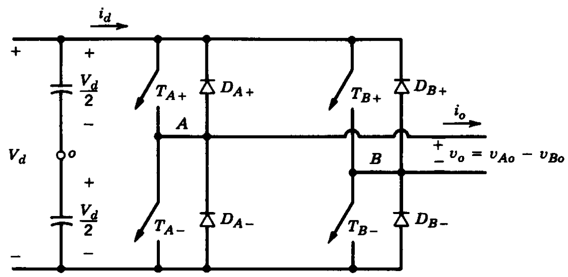
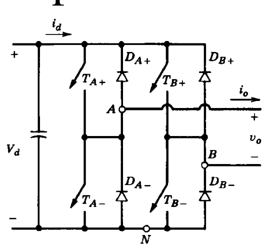


Figure 8-11 Single-phase full-bridge inverter.

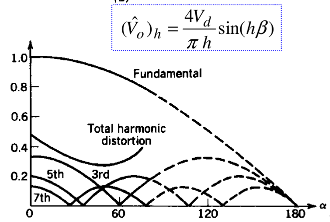
- For a square wave modulation/control scheme, the switches in the diagonals operate simultaneously: T_{A+}-T_{B-} ($V_o = V_d$) and T_{A-}-T_{B+} ($V_o = -V_d$).
- Fundamental output component is twice that of the half-bridge inverter.

Output control by voltage cancellation

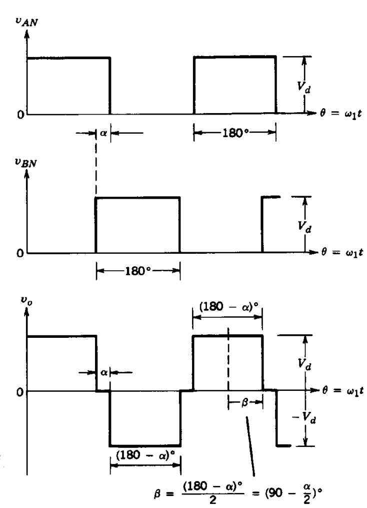


(a)

$$(\hat{V}_o)_h = \frac{4V_d}{\pi h}\sin(h\beta)$$

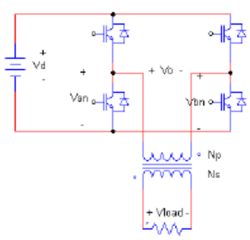


(c)



Example: Final 2011

Consider the emergency power supply shown below. The inverter is controlled with "voltage cancellation" to allow the regulation of the voltage across the load as the battery voltage (Vd) decreases. When the battery voltage is equal to rated value (48 V) the overlap angle (α) is equal to 91.2°. The turns ratio of the transformer (Np:Ns) is 1: 7.934. Each switch remains on for 10 ms and off for 10 ms. A) What is the frequency of the fundamental component of the load voltage? B) What is the magnitude of the fundamental component of the load voltage? C) What should be the value of the overlap angle when the battery voltage drops to 80% of its rated value so that the magnitude of the fundamental component of the load voltage remains regulated at the original value calculated in part B? (15 marks).



Full-bridge SPWM inverter

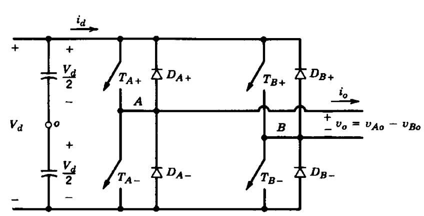


Figure 8-11 Single-phase full-bridge inverter.

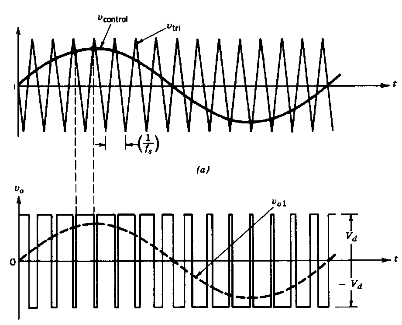


Figure 8-12 PWM with bipolar voltage switching.

- Bipolar PWM: Switches operate in pairs ($T_{A+}T_{B-}$ - $T_{B+}T_{A-}$).
- Voltage components are twice as large as those of the half-bridge inverter.

$$v_o = v_{Ao} - v_{Bo}$$

$$(\hat{V}_o)_1 = m_a V_d, \quad m_a = \frac{\hat{V}_{control}}{\hat{V}_{tri}} \le 1$$

http://www.ipes.ethz.ch/ipes/Inverter/e_H_Bruecke.html