Inverters

Lecture 14

Electrical Engineering Department

Power Electronics and Special Machine

By

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Important Notice

Note to Students:

These lecture materials are provided as supplementary support to help clarify and reinforce the concepts discussed in the main course lectures. They are not a substitute for the official course materials or the primary references assigned. Students are encouraged to refer to the original sources and attend the main lectures to ensure full understanding of the subject.

Inverters (DC-AC Converters)

A three-phase inverter circuit designed to converts the DC power into a three-phase AC power at a desired output voltage or current and frequency.

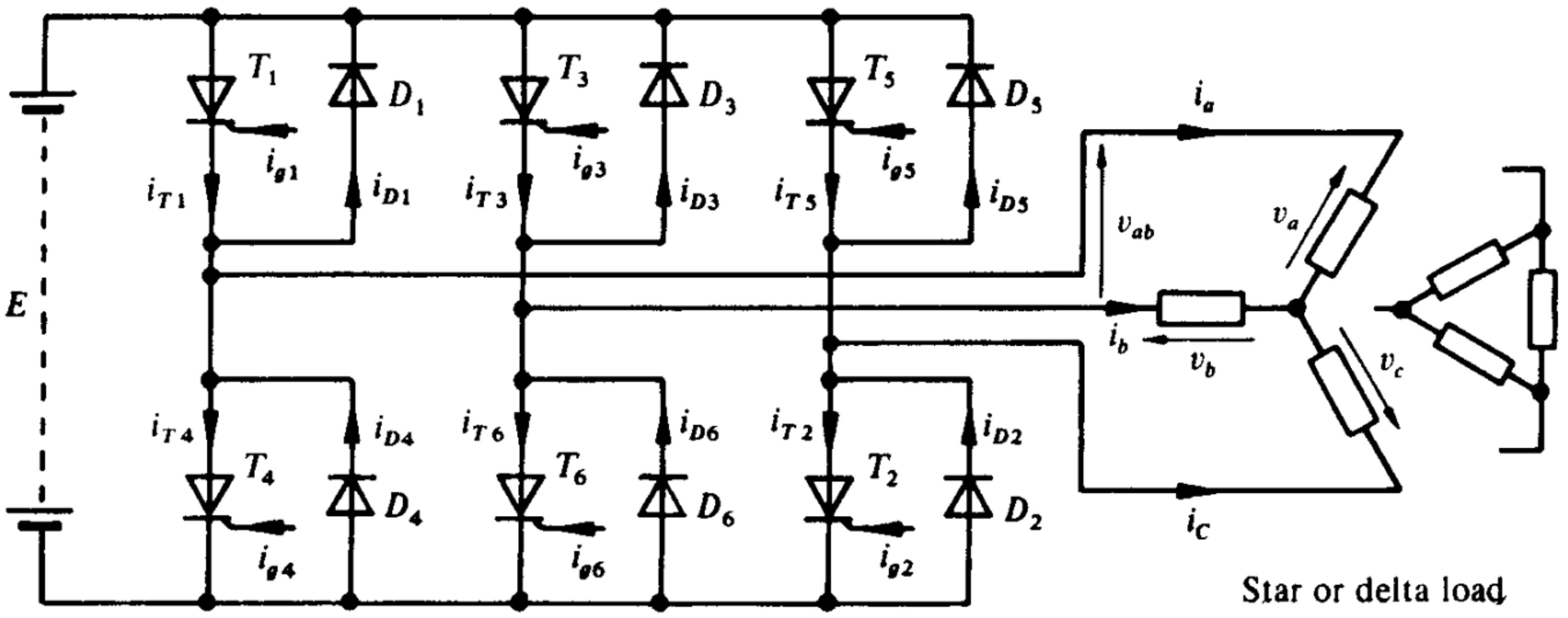
Inverters (DC-AC Converters)

Three-phase inverter circuit applications

- Uninterruptable power supplies (UPS).
- HVDC power transmission.

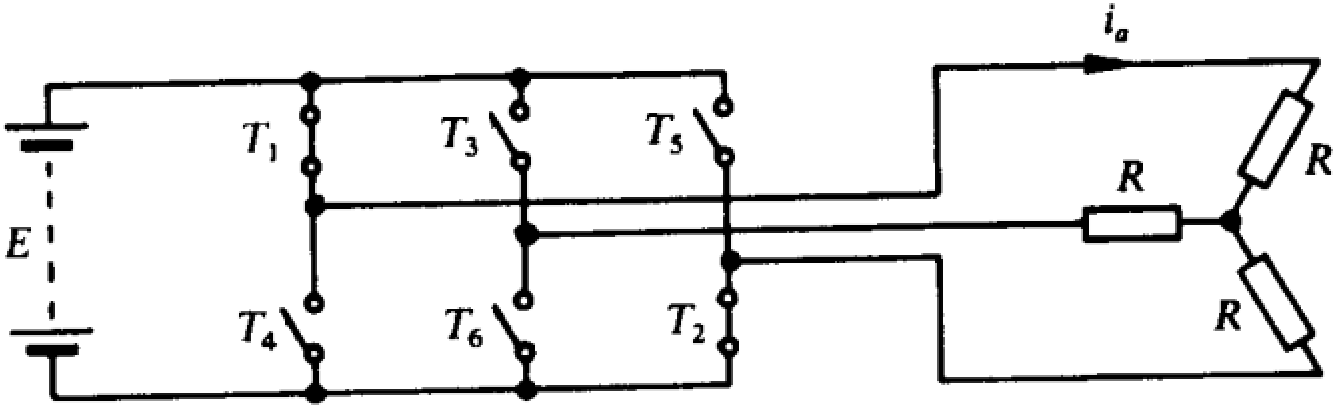
Three-phase inverter

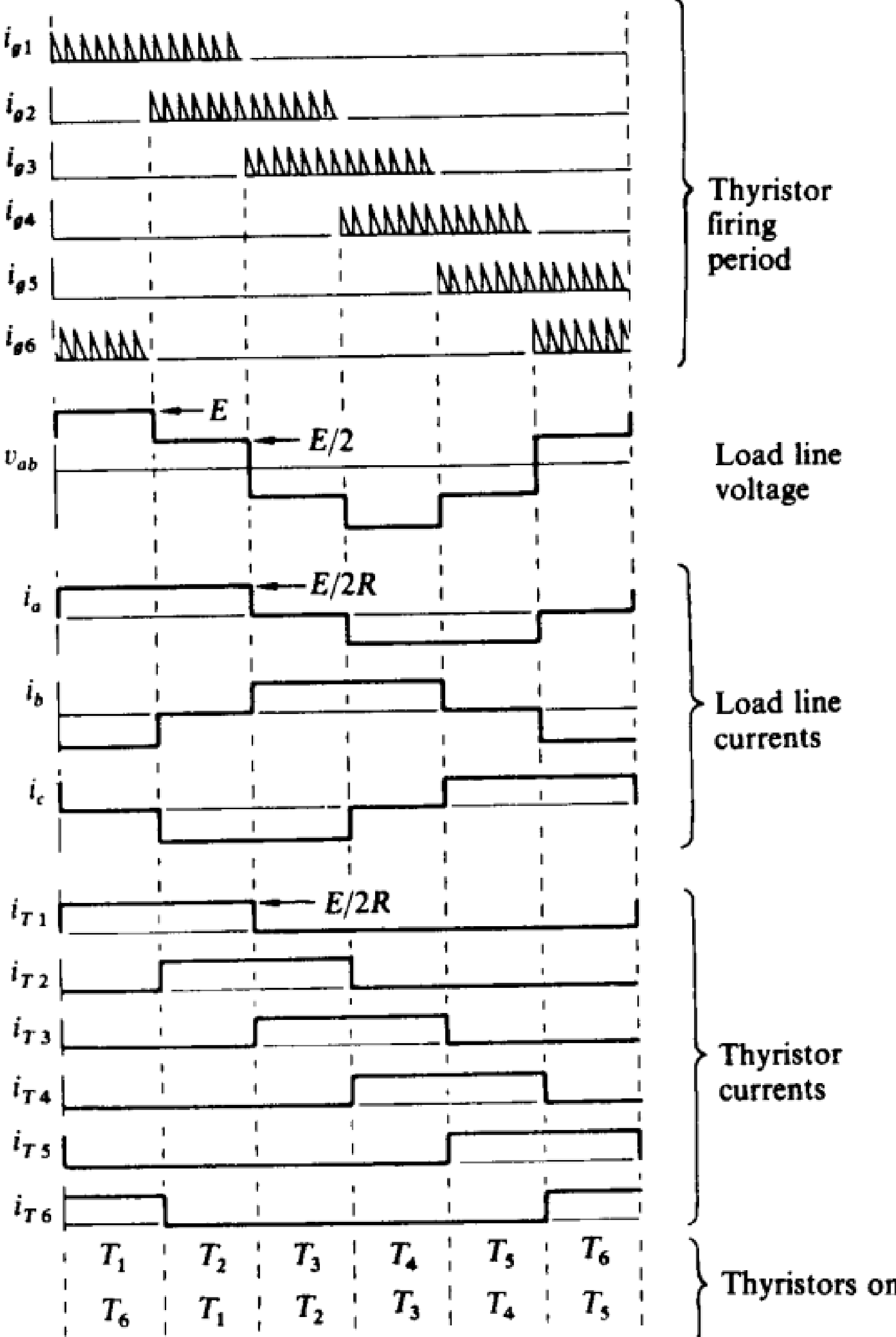
Three-phase voltage-source inverter basically includes 3 single phase inverter switches where each switch can be connected to one load terminal.



Three-phase inverter

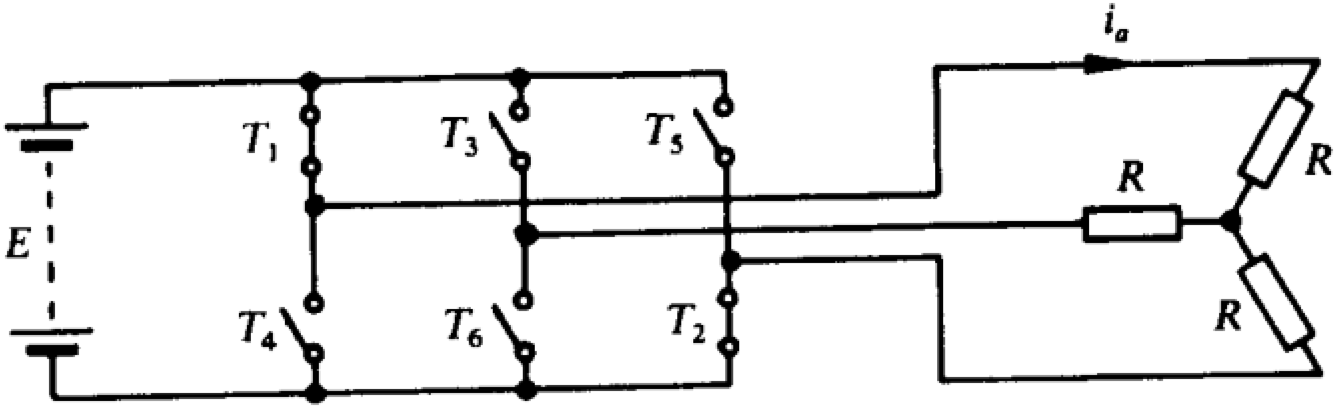
Three-phase voltage-source inverter (120 degree) with resistive load.

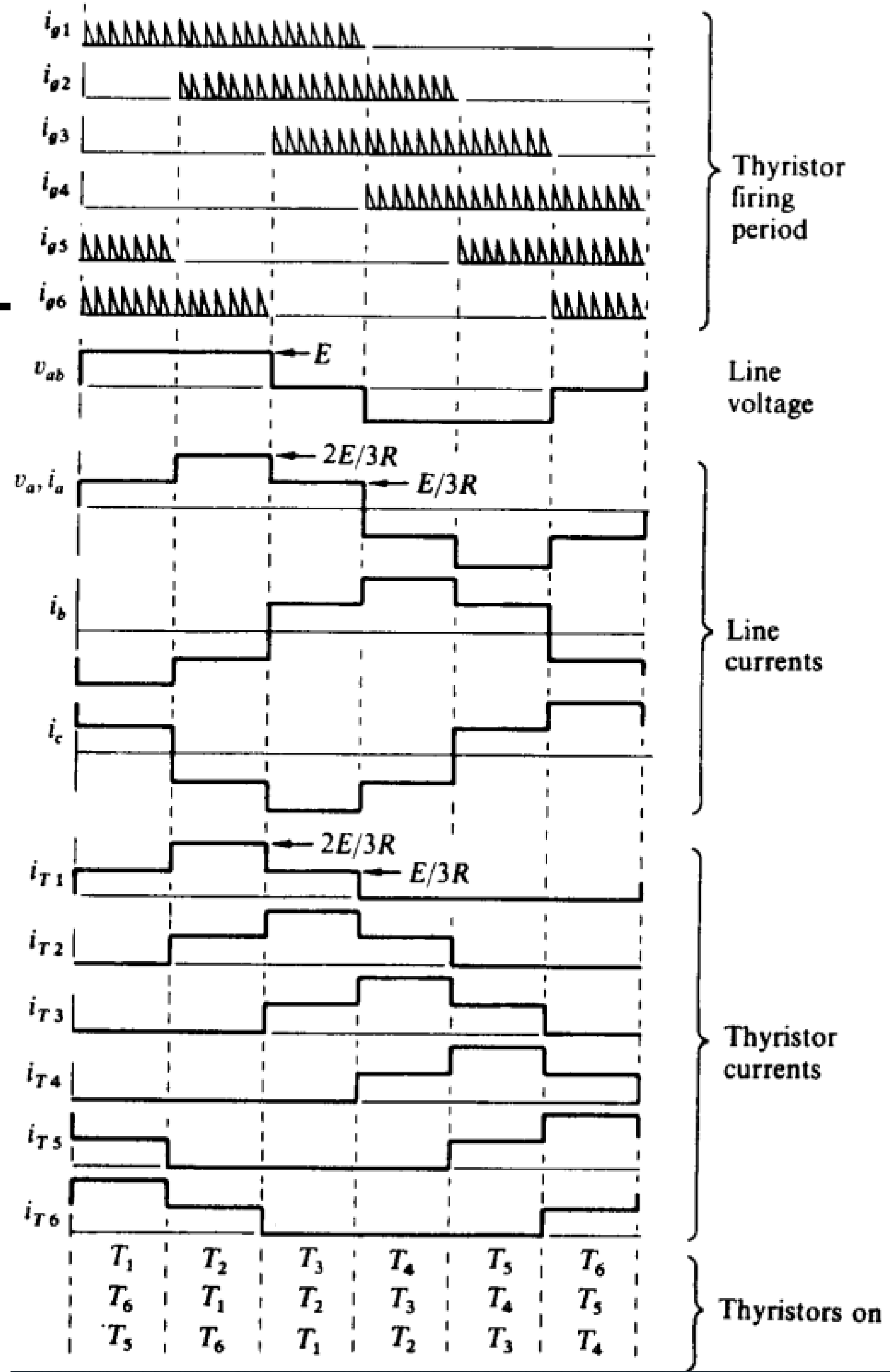




Three-phase inverter

Three-phase voltage-source inverter (180 degree) with resistive load.





Three-phase inverter

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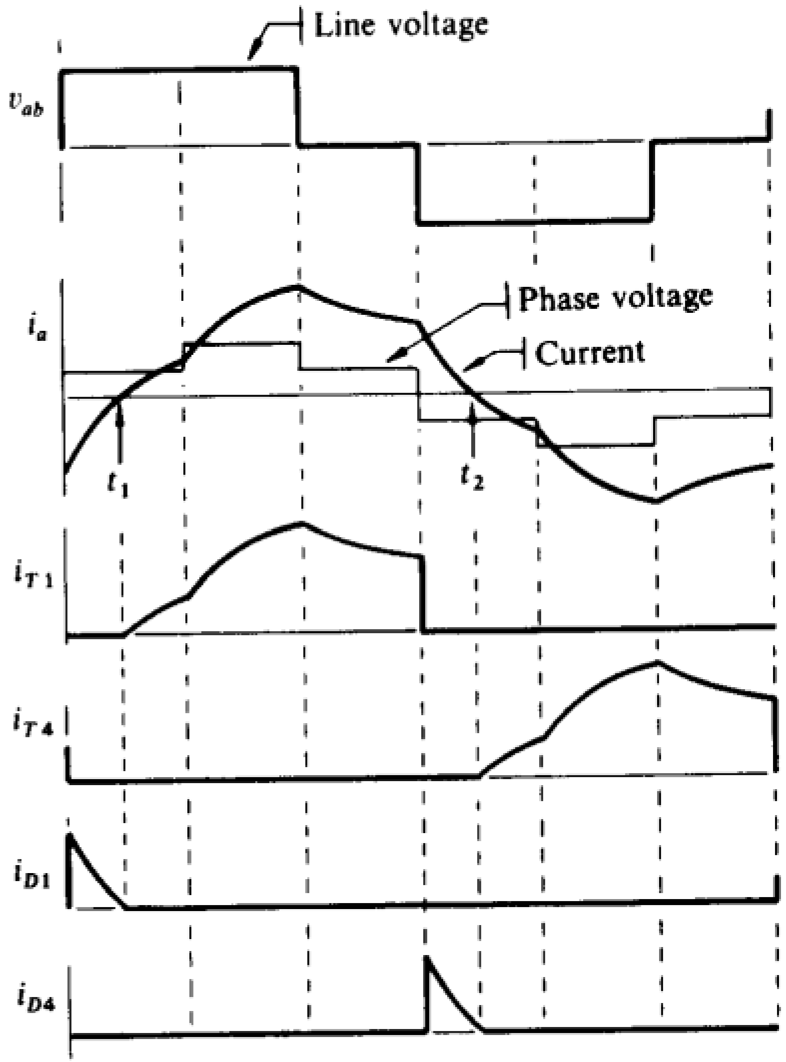
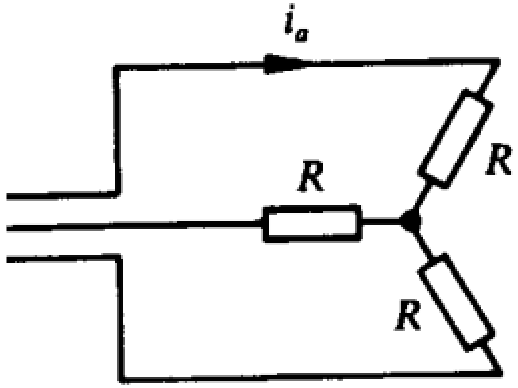
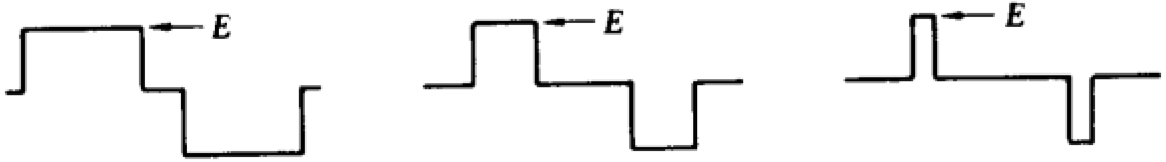






Single-phase inverter

Example: A three-phase bridge inverter is fed from a DC source of 200 V. If the load is star-connected of 10Ω/phase pure resistance, determine the RMS load current, the required RMS current rating of the thyristor, and the load power for 120° firing.

Solution: (i) 120° firing

Thyristor peak current $= \frac{E}{2\times R} = \frac{200}{2\times 10} = 10\ \mathrm{A}$

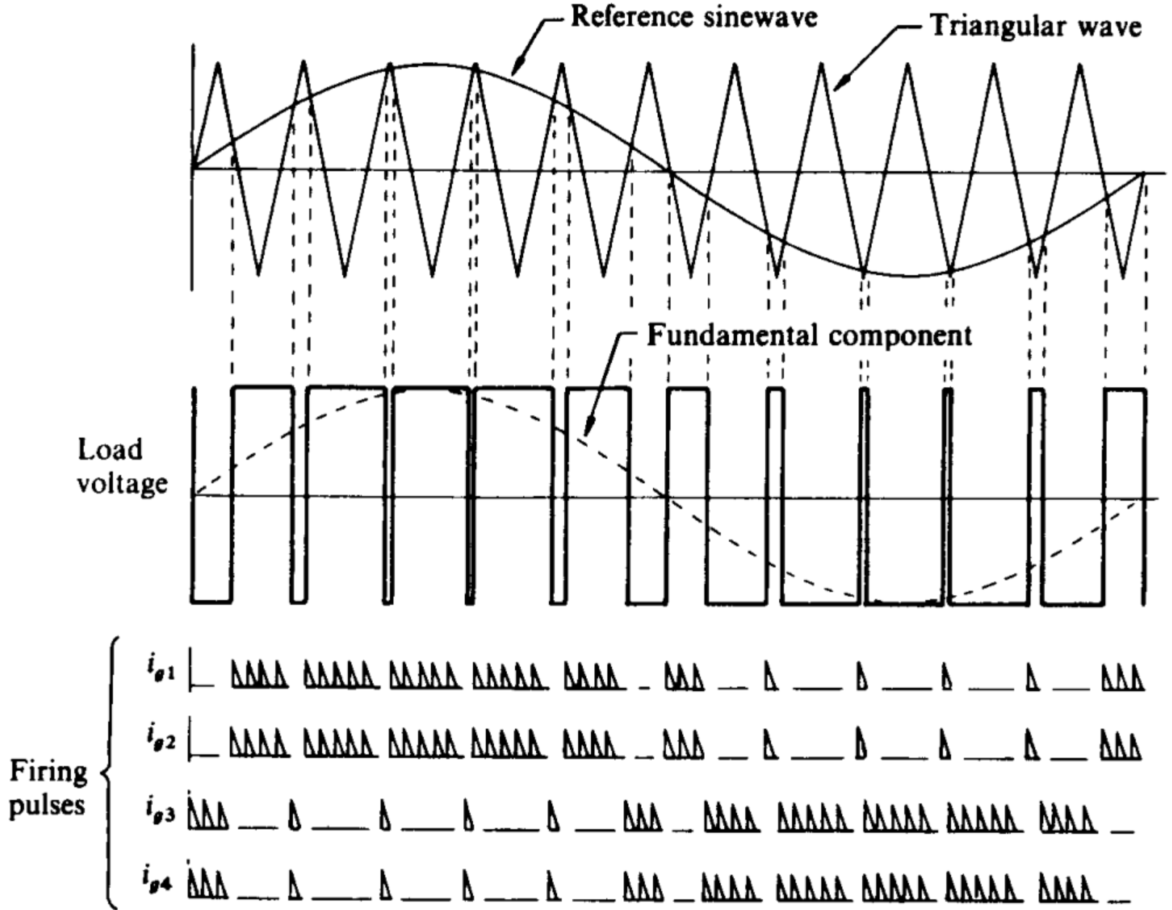
Thyristor RMS current $= 10\sqrt{3} = 5.8\ \mathrm{A}$

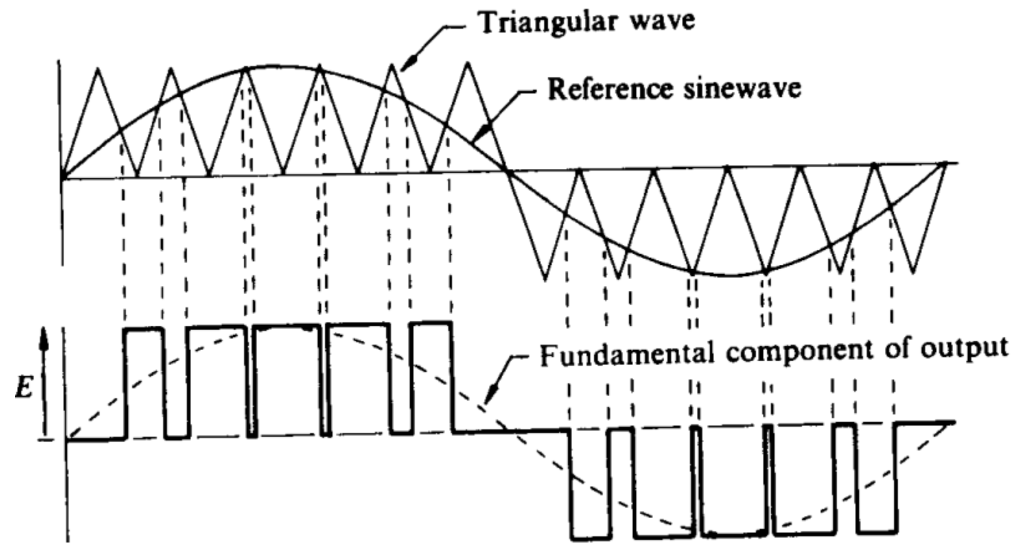
The RMS load current $= \frac{E}{2\times R}\sqrt{\frac{2}{3}} = 8.16\ \mathrm{A}$

Load power$= I_{RMS}^2 \times R = 8.16^2 \times 10 \times 3 = 2000\ W$

Single-phase inverter PWM

Pulse Width Modulation (PWM) is a highly efficient technique for controlling analogue devices (like thyristors) using a digital signal.

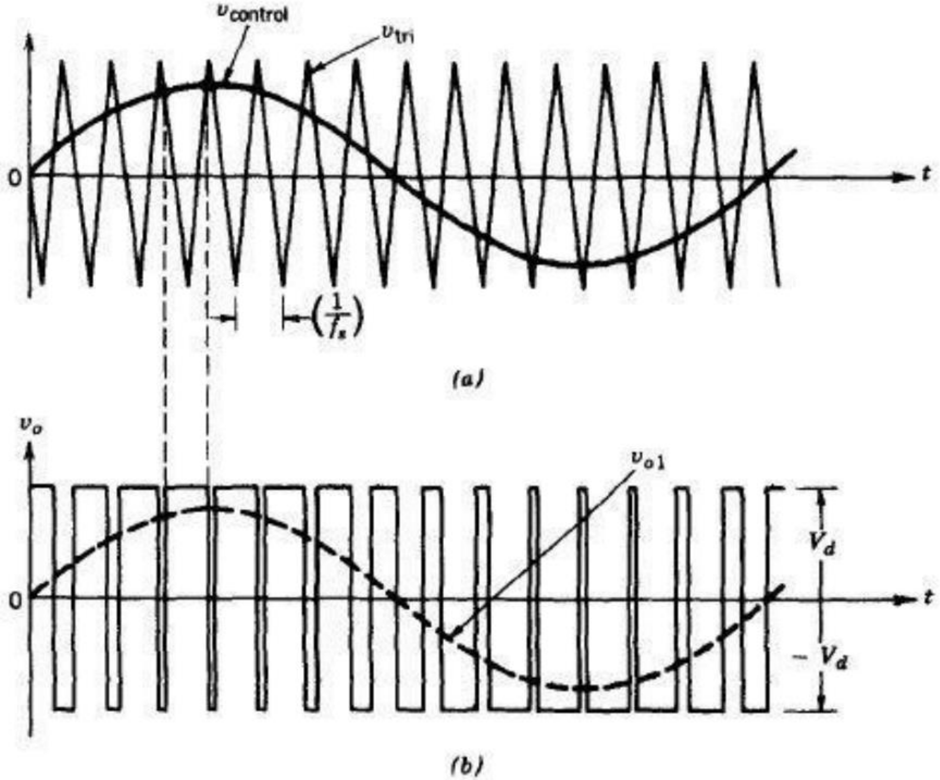




Single-phase inverter PWM

The amplitude modulation ratio $m_a = V_{cont}/V_{tri}$

Where V_{cont} is the peak amplitude of the control signal and V_{tri} is the amplitude of the triangular signal.



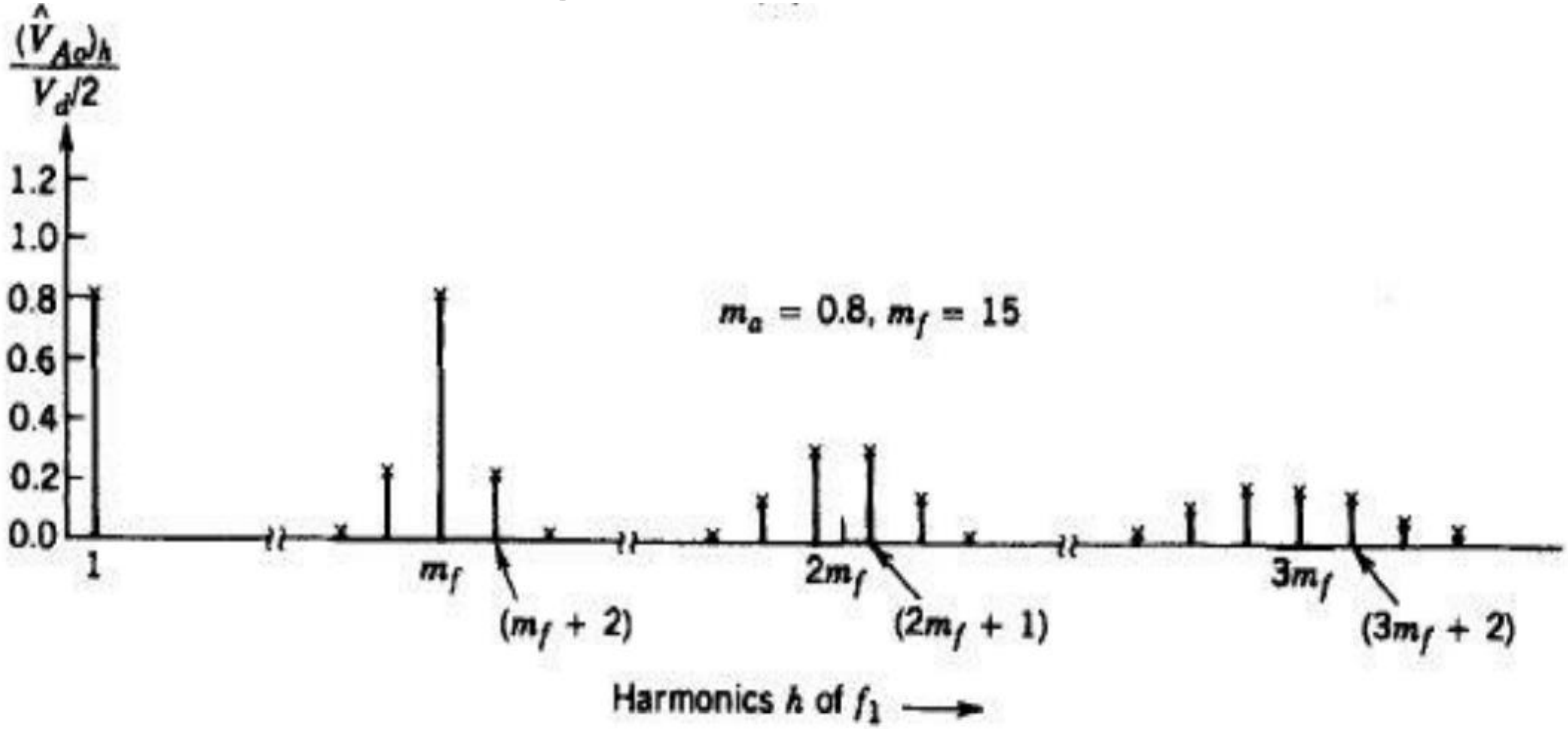
$m_a <= 1$ and $V_o = m_a x V_d$

The frequency modulation ratio defined as $m_f = f_s/f_i$

Where f_s is the switching frequency (carrier frequency) of the triangular signal and f_i is the modulating frequency.

Single-phase inverter PWM

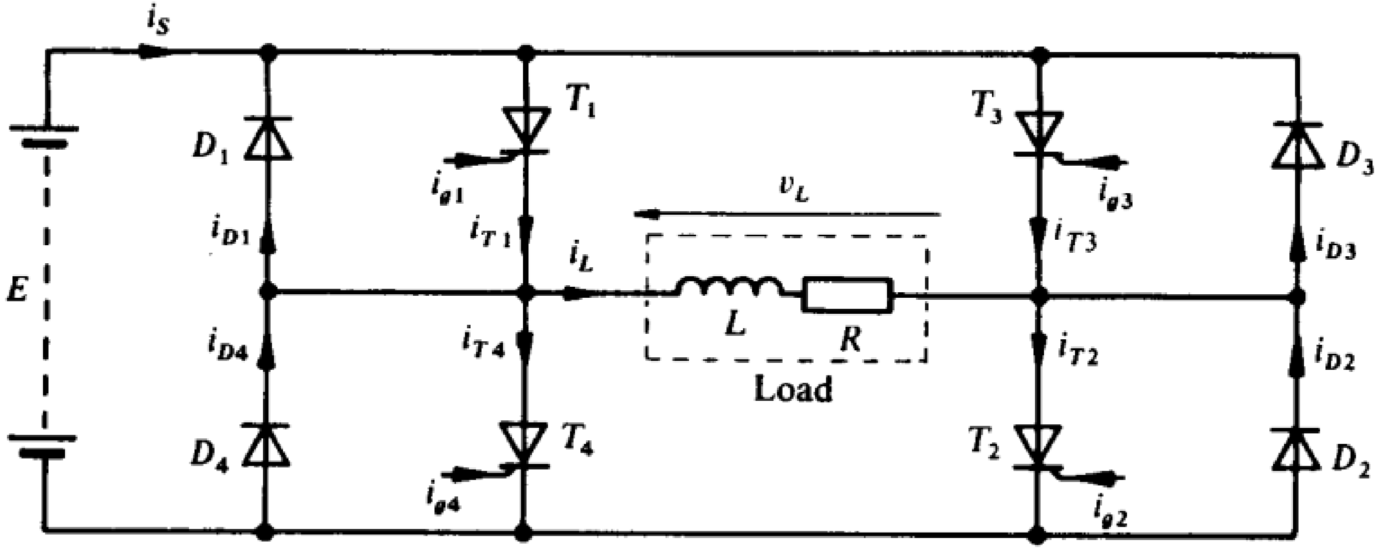
The control signal V_{cont} is used to modulate the switch duty ratio and has a frequency f_i which is the desired fundamental frequency of the inverter voltage output



Single-phase inverter PWM

Example 1: In the full-bridge inverter shown below, E=300 V, m_a=0.8, m_f=39 and the fundamental frequency is 50 Hz. Calculate the RMS values of the fundamental frequency and some dominate harmonics in the output voltage (V_L) if a PWM bipolar voltage-switching scheme is used.

Harmonics (h)	m_a=0.8
1	0.8
m_f	0.818
m_f+2, m_f-2	0.22
$2m_f$+1, $2m_f$-1	0.314
$2m_f$+3, $2m_f$-3	0.139



Single-phase inverter PWM

Solution: The RMS voltage at any harmonics h is given as;

$$V_L = \frac{E}{\sqrt{2}} \times m_a$$

$$V_{L(1)} = \frac{300}{\sqrt{2}} \times 0.8 = 169.7\,V\ at\ 50\ Hz$$

$$V_{L(37)} = \frac{300}{\sqrt{2}} \times 0.22 = 46.66\,V\ at\ 1850\ Hz = V_{L(41)}\ at\ 2050\ Hz$$

$$V_{L(39)} = \frac{300}{\sqrt{2}} \times 0.818 = 173.52\,V\ at\ 1950\ Hz$$

$$V_{L(77)} = \frac{300}{\sqrt{2}} \times 0.314 = 66.6\,V\ at\ 3850\ Hz = V_{L(79)}\ at\ 3950\ Hz$$

Single-phase inverter PWM

Example 2: If the load of inverter in Example1 is inductive load (R=5 ohm and L=5 mH). Find I_{L1} and I_{L39}

Solution:

$$Z_1 = \sqrt{R^2 + (n\omega L)^2} = \sqrt{5^2 + (1 \times 2 \times \pi \times 50 \times 5 \times 10^{-3})^2} = 5.24\ \Omega$$

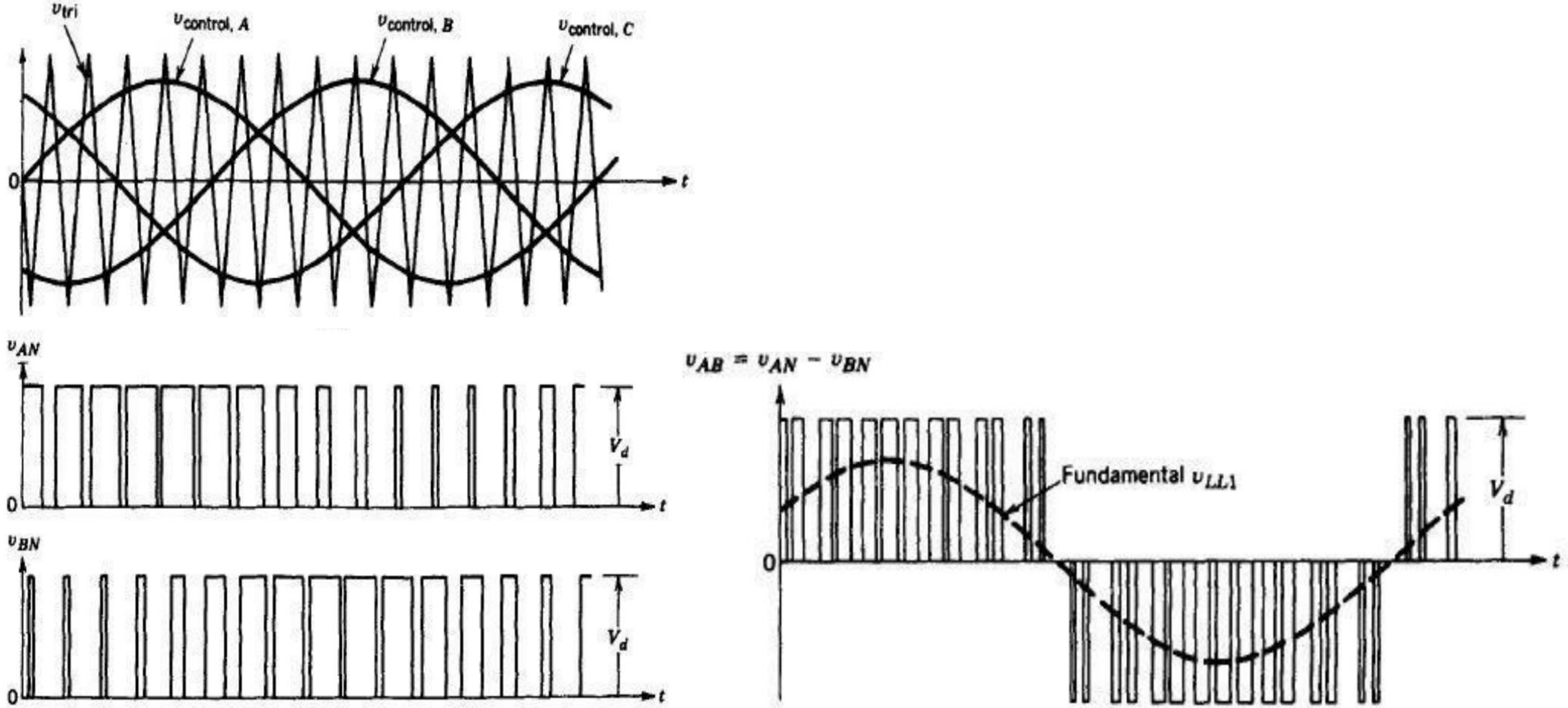
$$I_{L1} = \frac{V_{L(1)}}{Z_1} = \frac{169.7}{5.24} = 32.38\ A$$

$$Z_{39} = \sqrt{5^2 + (39 \times 2 \times \pi \times 50 \times 5 \times 10^{-3})^2} = 61.46\ \Omega$$

$$I_{L39} = \frac{V_{L(39)}}{Z_{39}} = \frac{173.52}{61.46} = 2.823\ A$$

Three-phase inverter PWM

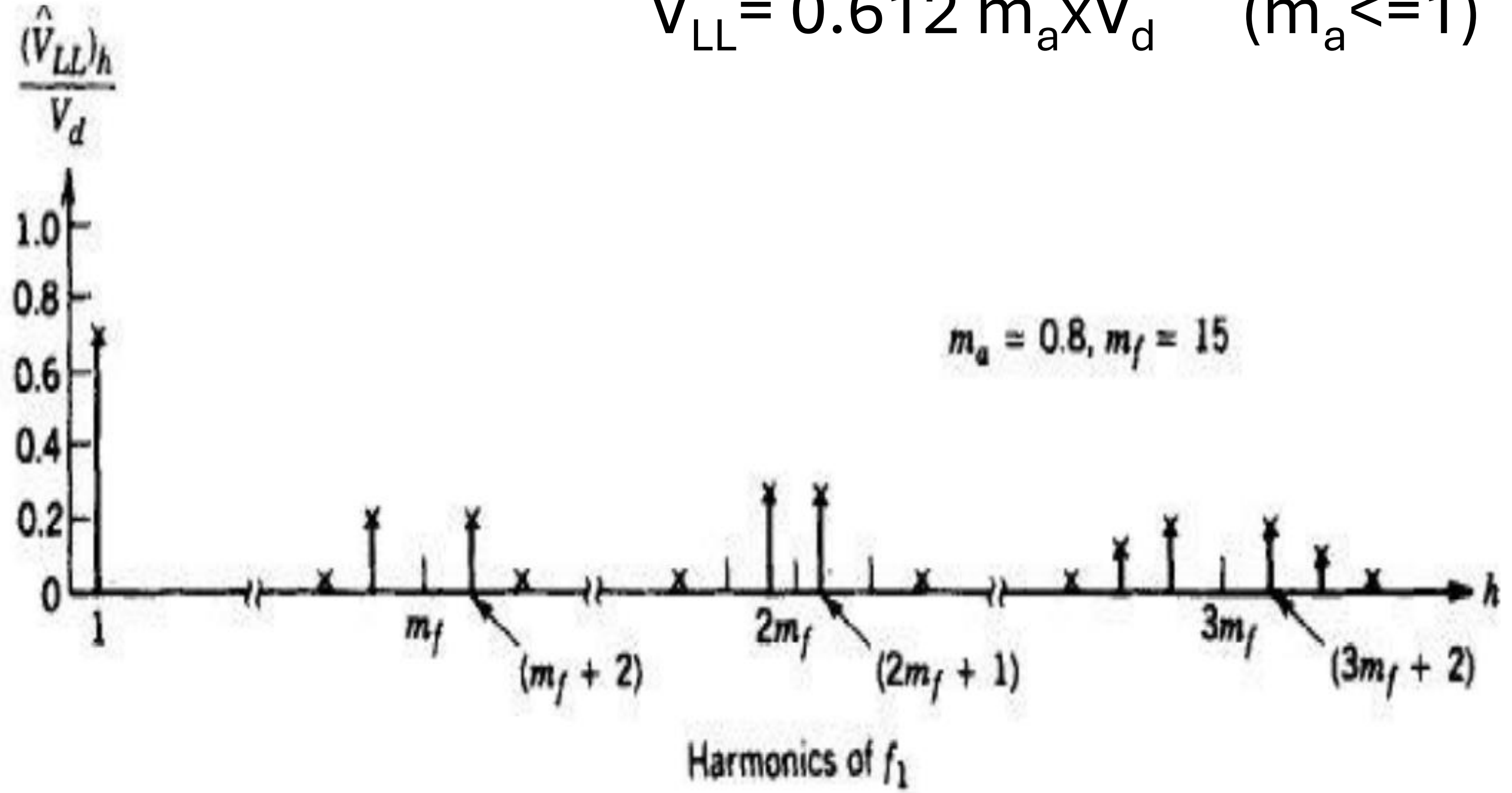
Three-phase PWM



Three-phase inverter PWM

The line-to-line rms voltage at the fundamental frequency, due to 120° phase displacement between phase voltages, can be written:

$$V_{LL} = 0.612\, m_a x V_d \qquad (m_a <= 1)$$



Three-phase inverter PWM

Example: Some generalized harmonics of V_{LL} voltage for a large and odd m_f that is an amplitude of three are:

Harmonics (h)\m_a	0.2	0.4	0.6	0.8	1
1	0.122	0.245	0.367	0.49	0.612
m_f+2, m_f-2	0.01	0.037	0.08	0.135	0.195
2m_f+1, 2m_f-1	0.116	0.2	0.277	0.192	0.111

Form above table and for V_d=750 V, m_a=0.8, m_f=45 and the fundamental frequency of 50 Hz. Calculate the RMS values of the fundamental frequency and some dominate harmonics in the output voltage V_{LL} and write the frequency of each harmonic. Note: the provided modulation index values are including the 0.612.

Three-phase inverter PWM

Solution:

The RMS voltage at any harmonics h is given as;

$$V_{LL(1)} = 0.490 \times 750 = 367.5\, V\ at\ 50\ Hz$$

$$V_{LL(43)} = 0.135 \times 750 = 101.25\, V\ at\ 2150\ Hz = V_{LL(47)}\ at\ 2350\ Hz$$

$$V_{LL(89)} = 0.192 \times 750 = 144\, V\ at\ 4450\ Hz = V_{LL(91)}\ at\ 4550\ Hz$$

Thanks for listening!