Power Electronics
No. 14: Three-phase Inverter

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Three-phase AC

Three-phase AC is the most common method used for the generation, transmission, and distribution of electric power.

Heavy users of electric power, such as factories, use three-phase AC. Light users, such as individual houses, use single-phase AC.

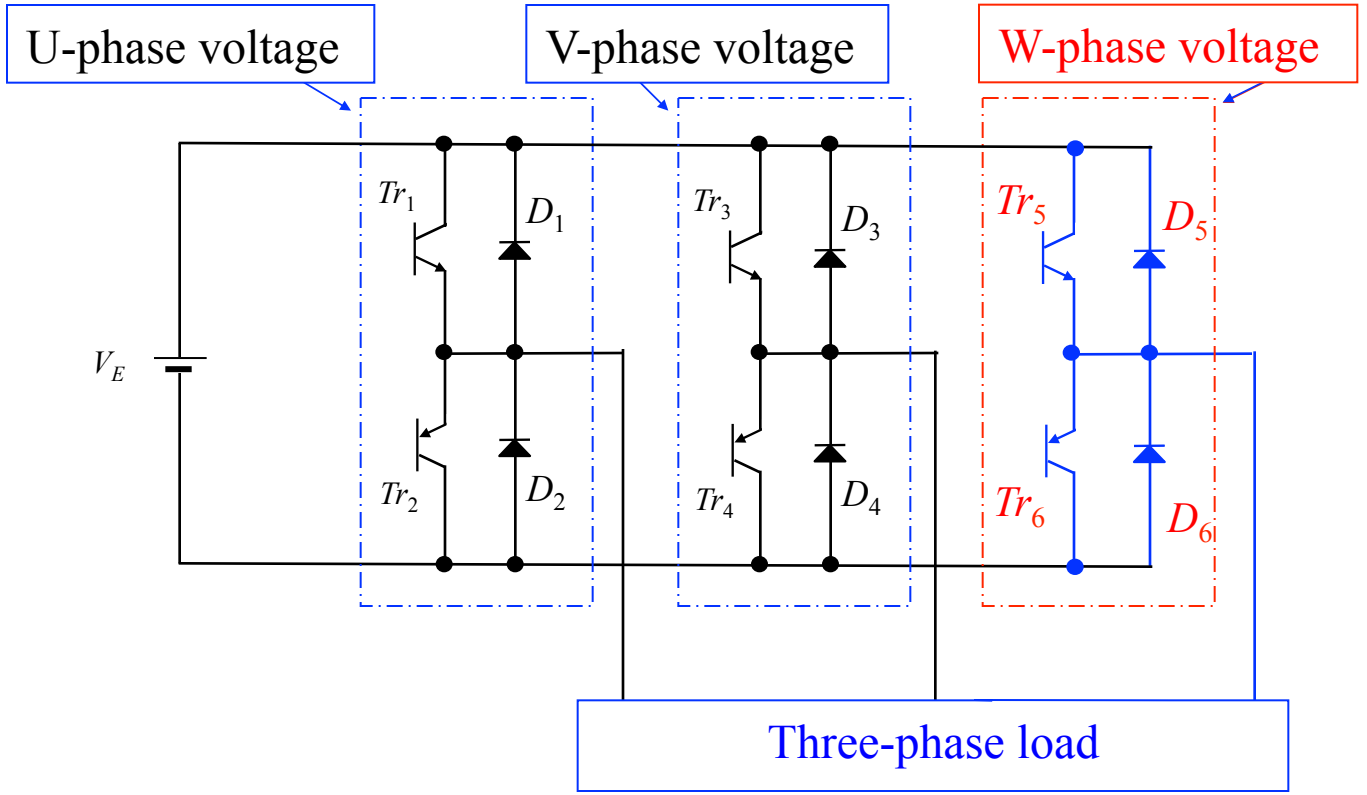
Most industry equipment uses three-phase AC.

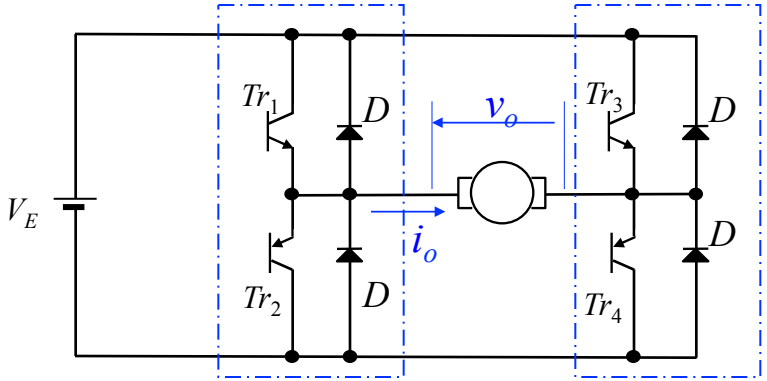
Motor: Three-phase induction motor
Shinkansen, subway trains
Three-phase synchronous motor
Brushless motor
Hybrid vehicles, Electric cars

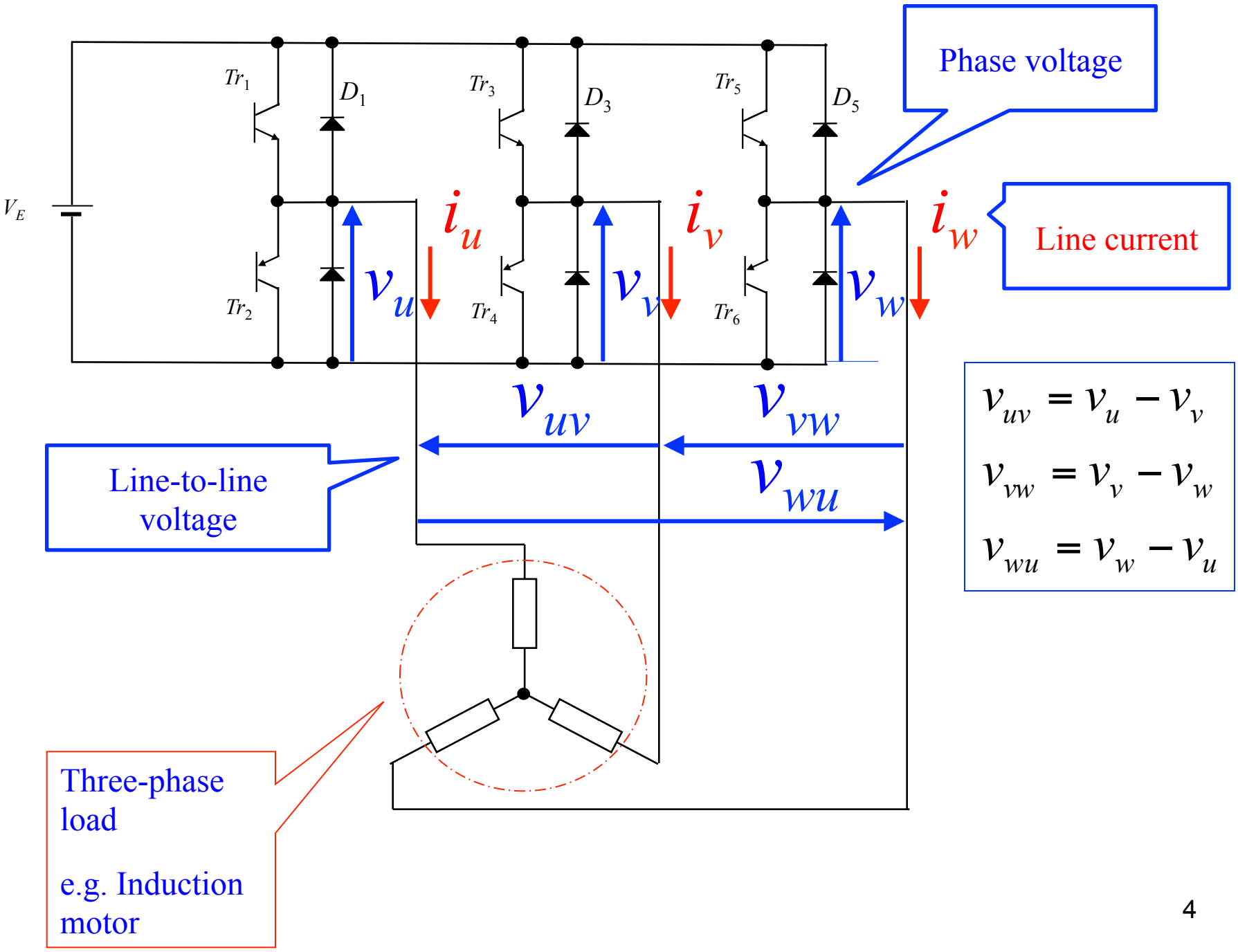
The small motors used in home appliances (such as refrigerators, washing machines, and electric fans) are single phase induction type motors.

Eco-generation systems (such as wind power generation, solar power generation, and fuel cell generation) also use three-phase AC to connect to the power grid.

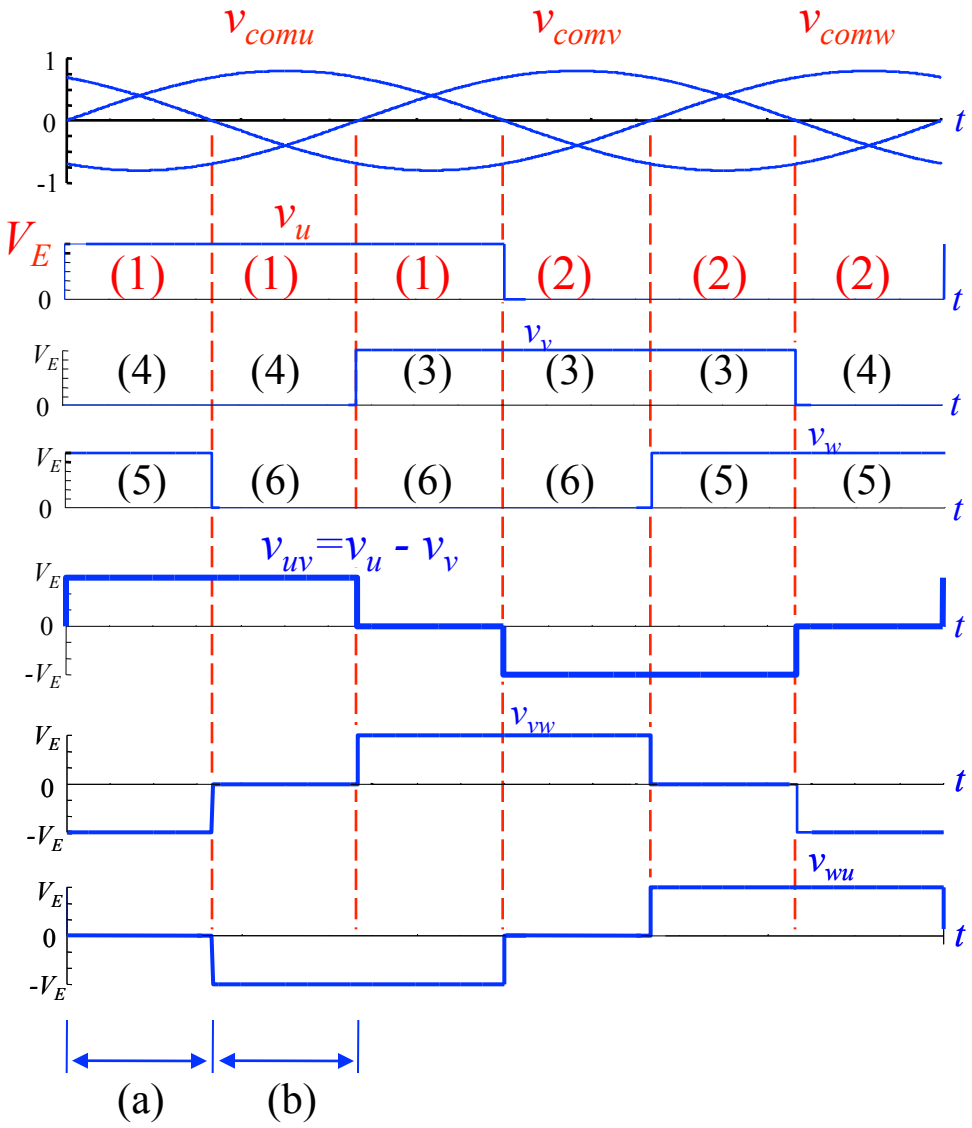
Three-phase inverter






Phase voltage
Line current
Line-to-line voltage
Three-phase load
e.g. Induction motor
V_E
Tr_1
Tr_2
Tr_3
Tr_4
Tr_5
Tr_6
D_1
D_3
D_5
i_u
i_v
i_w
v_u
v_v
v_w
v_{uv}
v_{vw}
v_{wu}
$v_{uv} = v_u - v_v$
$v_{vw} = v_v - v_w$
$v_{wu} = v_w - v_u$

120 degree conduction mode inverter

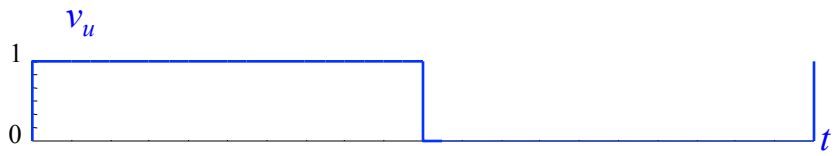


If $v_{comu} > 0$
Tr1 ON, Tr2 OFF
If $v_{comu} < 0$
Tr1 OFF, Tr2 ON

If $v_{comv} > 0$
Tr3 ON, Tr4 OFF
If $v_{comv} < 0$
Tr3 OFF, Tr4 ON

If $v_{comw} > 0$
Tr5 ON, Tr6 OFF
If $v_{comw} < 0$
Tr5 OFF, Tr6 ON

Fourier transform of phase voltage



$$v_u = a_0 + \sum_{n=1} a_n \cos n\theta + \sum_{n=1} b_n \sin n\theta$$

$$a_1 = \frac{1}{\pi}\int_0^{2\pi} v_u \cos\theta d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi} V_E \cos\theta d\theta$$

$$= \frac{V_E}{\pi}\left[\sin\theta\right]_0^{\pi}$$

$$= 0$$

$$b_1 = \frac{1}{\pi}\int_0^{2\pi} v_u \sin\theta d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi} V_E \sin\theta d\theta$$

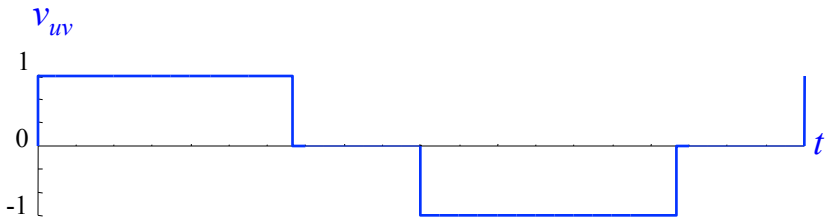
$$= \frac{V_E}{\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{2V_E}{\pi}$$

Fundamental component of phase voltage

$$v_{u1} = \frac{2V_E}{\pi}\sin\omega t$$

Fourier transform of line-to-line voltage



$$v_{uv} = a_0 + \sum_{n=1} a_n \cos n\theta + \sum_{n=1} b_n \sin n\theta$$

$$a_1 = \frac{1}{\pi}\int_0^{2\pi} v_{uv}\cos\theta d\theta$$

$$= \frac{1}{\pi}\left\{\int_0^{\frac{2\pi}{3}} V_E \cos\theta d\theta + \int_{\pi}^{\frac{5\pi}{3}} (-V_E)\cos\theta d\theta\right\}$$

$$= \frac{V_E}{\pi}\left\{\left[\sin\theta\right]_0^{\frac{2\pi}{3}} + \left[-\sin\theta\right]_{\pi}^{\frac{5\pi}{3}}\right\}$$

$$= \frac{\sqrt{3}V_E}{\pi}$$

$$b_1 = \frac{1}{\pi}\int_0^{2\pi} v_{uv}\sin\theta d\theta$$

$$= \frac{1}{\pi}\left\{\int_0^{\frac{2\pi}{3}} V_E \sin\theta d\theta + \int_{\pi}^{\frac{5\pi}{3}} (-V_E)\sin\theta d\theta\right\}$$

$$= \frac{V_E}{\pi}\left\{\left[-\cos\theta\right]_0^{\frac{2\pi}{3}} + \left[\cos\theta\right]_{\pi}^{\frac{5\pi}{3}}\right\}$$

$$= \frac{3V_E}{\pi}$$

Fundamental component of line - to - line voltage

$$v_{uv1} = \frac{V_E}{\pi}\left(3\sin\omega t + \sqrt{3}\cos\omega t\right)$$

$$= \frac{2\sqrt{3}V_E}{\pi}\left(\frac{\sqrt{3}}{2}\sin\omega t + \frac{1}{2}\cos\omega t\right)$$

$$= \frac{2\sqrt{3}V_E}{\pi}\left(\cos\frac{\pi}{6}\sin\omega t + \sin\frac{\pi}{6}\cos\omega t\right)$$

$$= \frac{2\sqrt{3}V_E}{\pi}\sin\left(\omega t + \frac{\pi}{6}\right)$$

The amplitude and phase of line-to-line voltage is $\sqrt{3}$ times larger than and π/6 leading to those of the phase voltage.

STEP 10. Circuit construction practice

Design and construct a D-class amplifier using a full-bridge inverter.