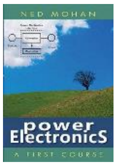
EEEN313/ECEN405

Converters for Electric Drives

Reading: Chapter 11: Ned Mohan – Power Electronics A first Course



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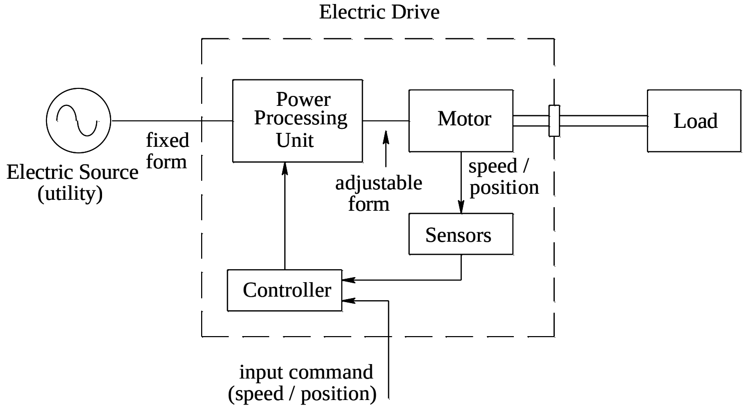
Adjustable-Speed Drive:



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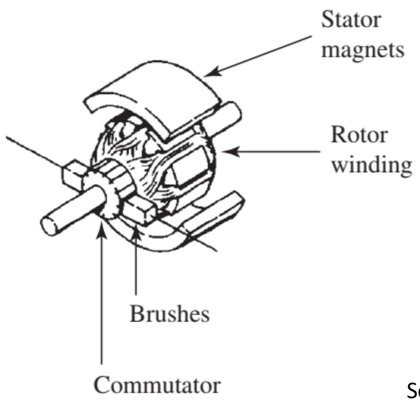
DC MOTORS



Source: Electro-Craft Corporation.

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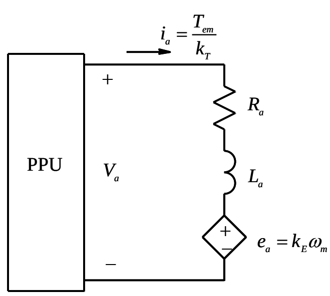
DC-Machine Equivalent Circuit

$$v_a = e_a + R_a\, \mathrm{i}_a + L_a \frac{di_a}{dt}$$

$$\frac{d\omega_m}{dt} = \frac{1}{J_{eq}}(T_{em} - T_L)$$



$$k_T = k_E$$

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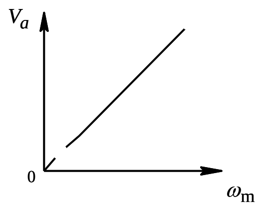
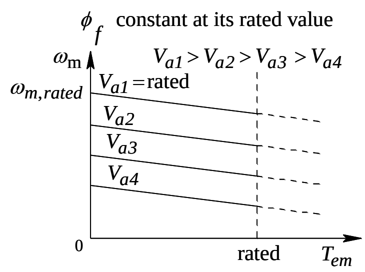
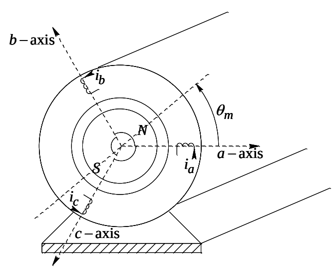
Torque-Speed Characteristics

$$V_a = k_E \omega_m + R_a I_a \qquad I_a = \frac{T_{em}(=T_L)}{k_T}$$

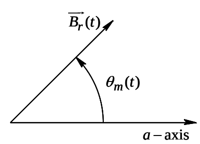




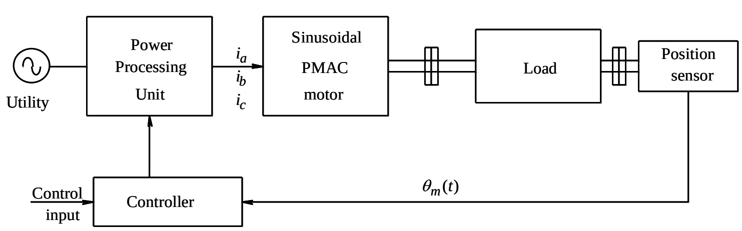
PERMANENT-MAGNET AC MACHINES



(a)



(b)



In ac steady state, accounting all three-phases, the input electric power, supplied by the current in opposition to the induced back-emf, equals the mechanical output power

$$T_{em}\,\omega_m = 3\underbrace{(k_{E,phase}\,\omega_m)}_{E_{\text{rms}}}\,I_{\text{rms}}$$

The torque contribution of each phase is $T_{em}/3$, $\quad T_{em,phase} = \dfrac{T_{em}}{3} = k_{E,phase}\,I_{\text{rms}}$

The electromagnetic torque acts on the mechanical system connected to the rotor, and the resulting speed ω_m can be obtained from the equation

$$\frac{d\omega_m}{dt} = \frac{T_{em}-T_L}{J_{eq}} \Rightarrow \omega_m(t) = \omega_m(0) + \frac{1}{J_{eq}}\int_0^t (T_{em}-T_L)\cdot d\tau$$

where J_{eq} is the combined motor-load inertia and T_L is the load torque, which may include friction. The rotor position $\theta_m(t)$ is,

$$\theta_m(t) = \theta_m(0) + \int_0^t \omega_m(\tau)\cdot d\tau$$

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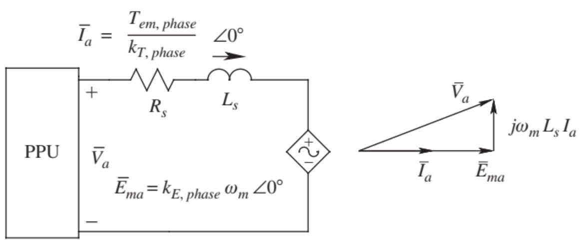
PERMANENT-MAGNET AC MACHINES – Equivalent Circuit



(a) (b)

In the ac steady state, using phasors, the current I_a is ensured by the feedback control to be in phase with the phase-a induced voltage E_{ma}.
The phase currents produce the total electromagnetic torque necessary to rotate the mechanical load at a speed ω_m.
The induced back-emf $E_{ma} = E_{rms}\angle 0°$, whose rms magnitude is linearly proportional to the speed of rotation ω_m, is represented by a dependent voltage-source.

The applied voltage V_a in Figure ***a*** overcomes the back-emf E_{ma} and causes the current I_a to flow. The frequency of the phasors in Hz equals $\omega_m/(2\pi)$ in a 2-pole PMAC machines.
There is a voltage drop across both the per-phase stator winding resistance R_s (neglected here) and a per-phase inductance L_s, which is the sum of the leakage inductance L_{ls} caused by the leakage flux of the stator winding, and L_m due to the effect of the combined flux produced by the currents flowing in the stator phases.

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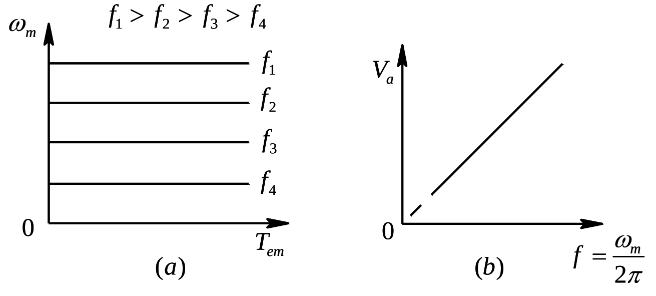
PMAC Torque-Speed Characteristics



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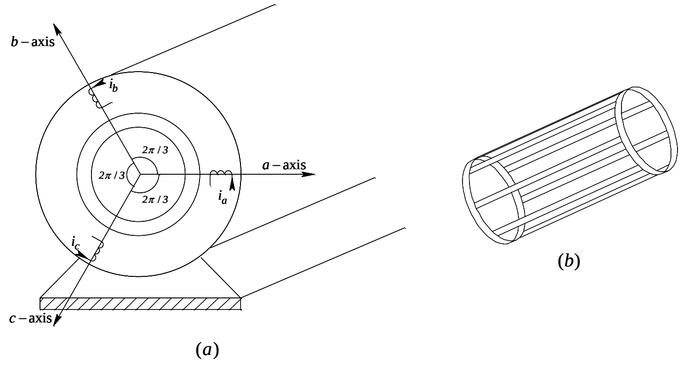
Induction Machines



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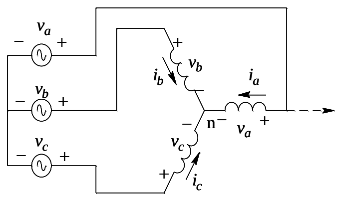
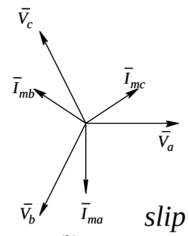
Principles of Induction Motor Operation





(a) (b)

slip frequency $\quad f_{slip} = \dfrac{\omega_{slip}}{\omega_{syn}} f$

$$\bar{V}_a = V_{rms}\angle 0^o, \quad \bar{V}_b = V_{rms}\angle -120^o, \text{ and } \bar{V}_c = V_{rms}\angle -240^o$$

$$\bar{I}_{ma} = \mathrm{I}_m\angle -90^o, \quad \bar{I}_{mb} = \mathrm{I}_m\angle -210^o, \text{ and } \bar{I}_{mc} = \mathrm{I}_m\angle -330^o$$

$$\omega_{syn} = 2\pi f$$

$$\omega_{syn} = \frac{2\pi f}{p/2} \quad \text{for a } p\text{-pole machine}$$

slip speed $\quad \omega_{slip} = \omega_{syn} - \omega_m$

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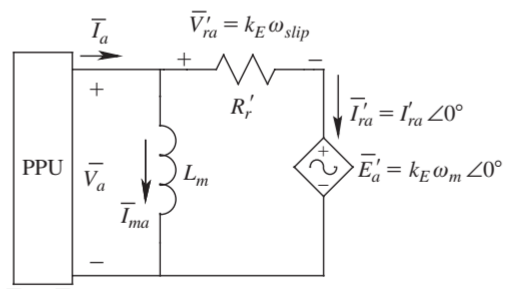
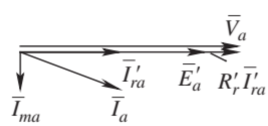
Principles of Induction Motor Operation – Equivalent Circuit



$\bar{V}_a = \bar{E}_{ma} = k_E\omega_{syn} = \angle 0°$



(a) (b)

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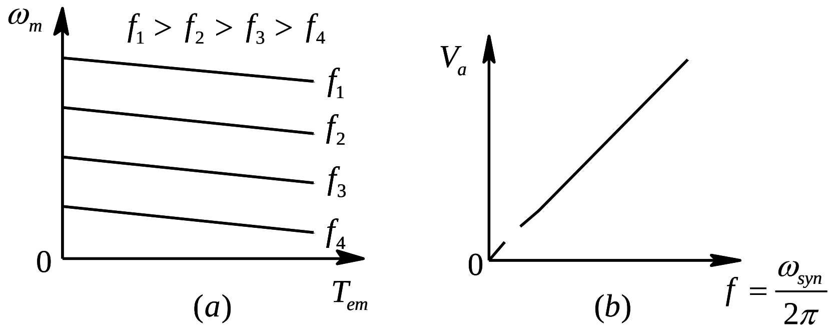

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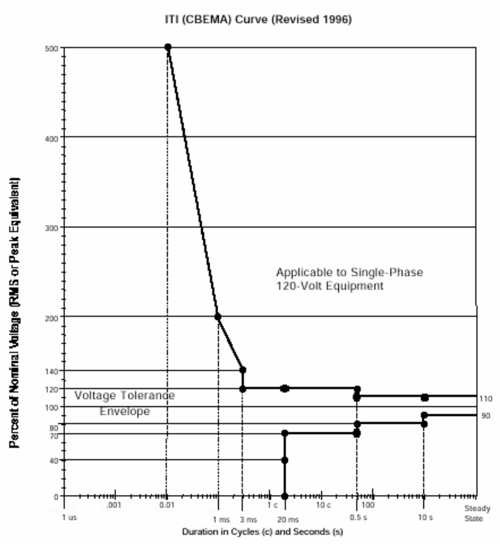
UNINTERRUPTIBLE POWER SUPPLIES (UPS)



CBEMA Curve

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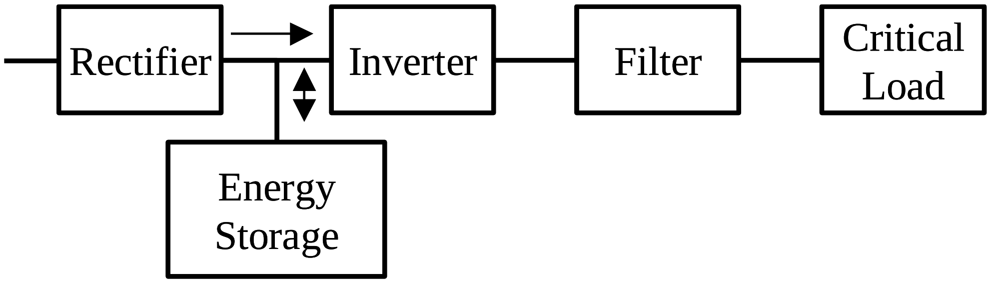
UNINTERRUPTIBLE POWER SUPPLIES (UPS)



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Summary

- Converter Voltage and Current Ratings in
  - Electric Drives
  - UPS

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