

## Formulae for electrical power technology

### Three-phase systems

$$\text{Star } I_L = I_p \quad V_L = \sqrt{3} V_p$$

$$\text{Delta } V_L = V_p \quad I_L = \sqrt{3} I_p$$

$$P = \sqrt{3} V_L I_L \cos \phi \quad \text{or} \quad P = 3 I_p^2 R_p$$

Two-wattmeter method:

$$P = P_1 + P_2 \quad \tan \phi = \sqrt{3} \frac{(P_1 - P_2)}{(P_1 + P_2)}$$

### Transformers

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} \quad I_0 = \sqrt{(I_M^2 + I_C^2)}$$

$$I_M = I_0 \sin \phi_0 \quad I_C = I_0 \cos \phi_0$$

$$E = 4.44 f \Phi_m N$$

$$\text{Regulation} = \left( \frac{E_2 - E_1}{E_2} \right) \times 100\%$$

$$\text{Equivalent circuit: } R_e = R_1 + R_2 \left( \frac{V_1}{V_2} \right)^2$$

$$X_e = X_1 + X_2 \left( \frac{V_1}{V_2} \right)^2 \quad Z_e = \sqrt{(R_e^2 + X_e^2)}$$

$$\text{Efficiency, } \eta = 1 - \frac{\text{losses}}{\text{input power}}$$

$$\text{Output power} = V_2 I_2 \cos \phi_2$$

$$\text{Total loss} = \text{copper loss} + \text{iron loss}$$

$$\text{Input power} = \text{output power} + \text{losses}$$

$$\text{Resistance matching: } R_1 = \left( \frac{N_1}{N_2} \right)^2 R_L$$

### D.c. machines

$$\text{Generated e.m.f. } E = \frac{2p\Phi nZ}{c} \propto \Phi \omega$$

( $c = 2$  for wave winding,  $c = 2p$  for lap winding)

$$\text{Generator: } E = V + I_a R_a$$

$$\text{Efficiency, } \eta = \left( \frac{VI}{VI + I_a^2 R_a + I_f V + C} \right) \times 100\%$$

$$\text{Motor: } E = V - I_a R_a$$

$$\text{Efficiency, } \eta = \left( \frac{VI - I_a^2 R_a - I_f V - C}{VI} \right) \times 100\%$$

$$\text{Torque} = \frac{EI_a}{2\pi n} = \frac{p\Phi Z I_a}{\pi c} \propto I_a \Phi$$

### Three-phase induction motors

$$n_s = \frac{f}{p} \quad s = \left( \frac{n_s - n_r}{n_s} \right) \times 100$$

$$f_r = sf \quad X_r = s X_2$$

$$I_r = \frac{E_r}{Z_r} = \frac{s \left( \frac{N_2}{N_1} \right) E_1}{\sqrt{[R_2^2 + (s X_2)^2]}} \quad s = \frac{I_r^2 R_2}{P_2}$$

Efficiency,

$$\eta = \frac{\text{input} - \text{stator loss} - \text{rotor copper loss} - \text{friction \& windage loss}}{\text{input power}}$$

Torque,

$$T = \left( \frac{m \left( \frac{N_2}{N_1} \right)^2}{2\pi n_s} \right) \left( \frac{s E_1^2 R_2}{R_2^2 + (s X_2)^2} \right) \propto \frac{s E_1^2 R_2}{R_2^2 + (s X_2)^2}$$

These formulae are available for downloading at the website:

[www.routledge.com/cw/bird](http://www.routledge.com/cw/bird)