Generation

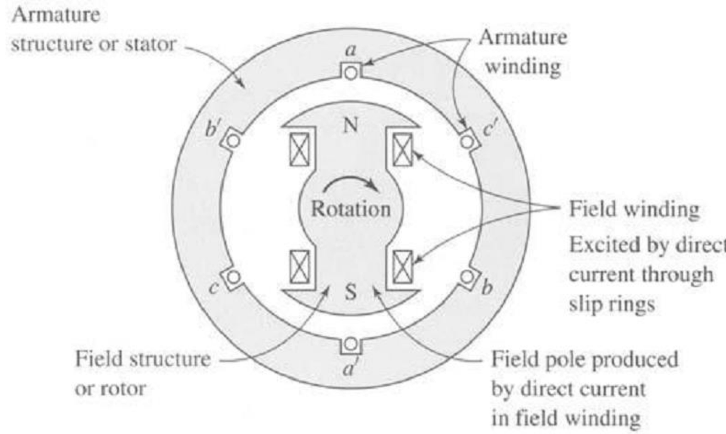
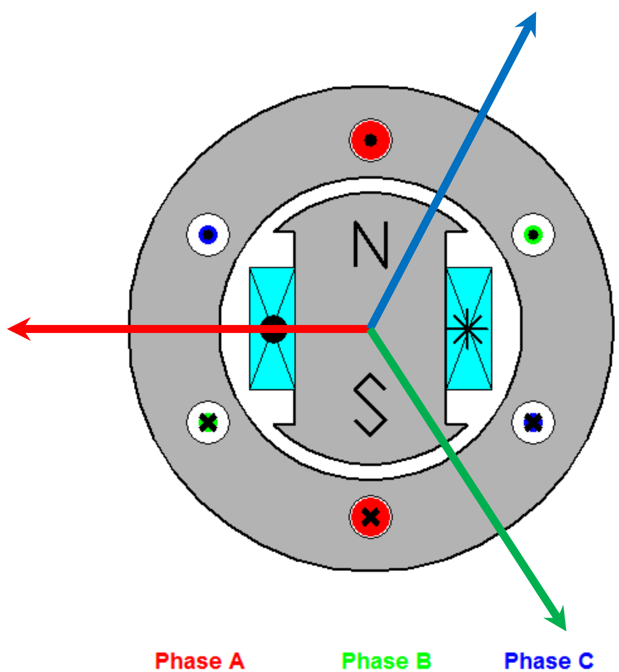
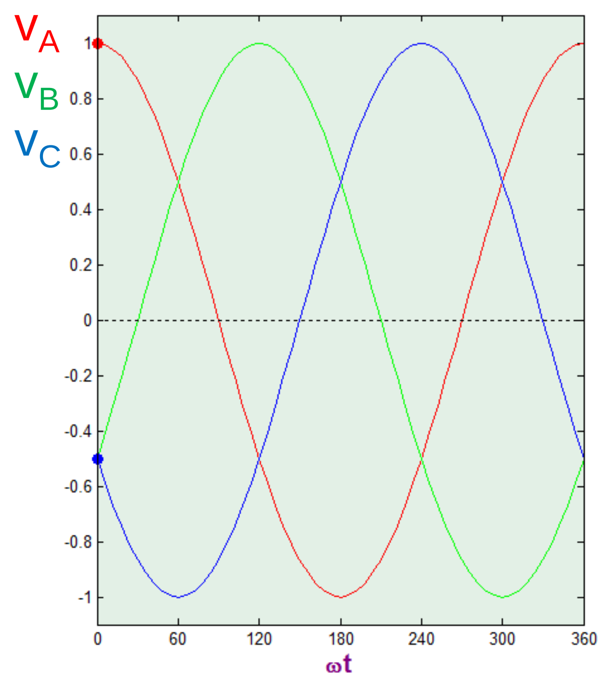


Figure A.1 Elementary two-pole, three-phase generator.





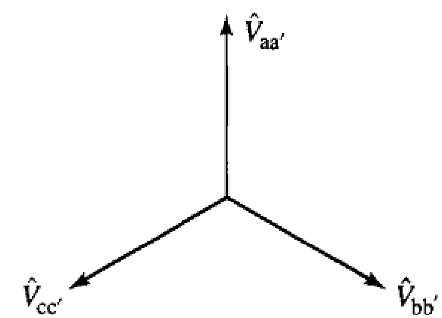
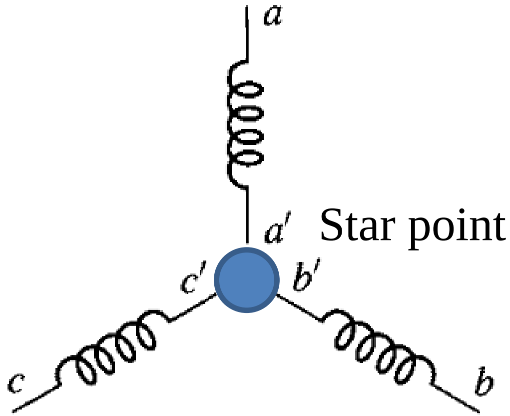


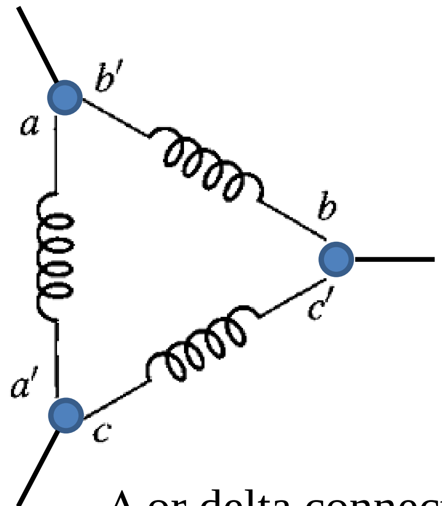
Figure A.4 Phasor diagram of generated voltages.

http://www.ece.umn.edu/users/riaz/animations/alternator.html

Connection



Y or star connection



Δ or delta connection

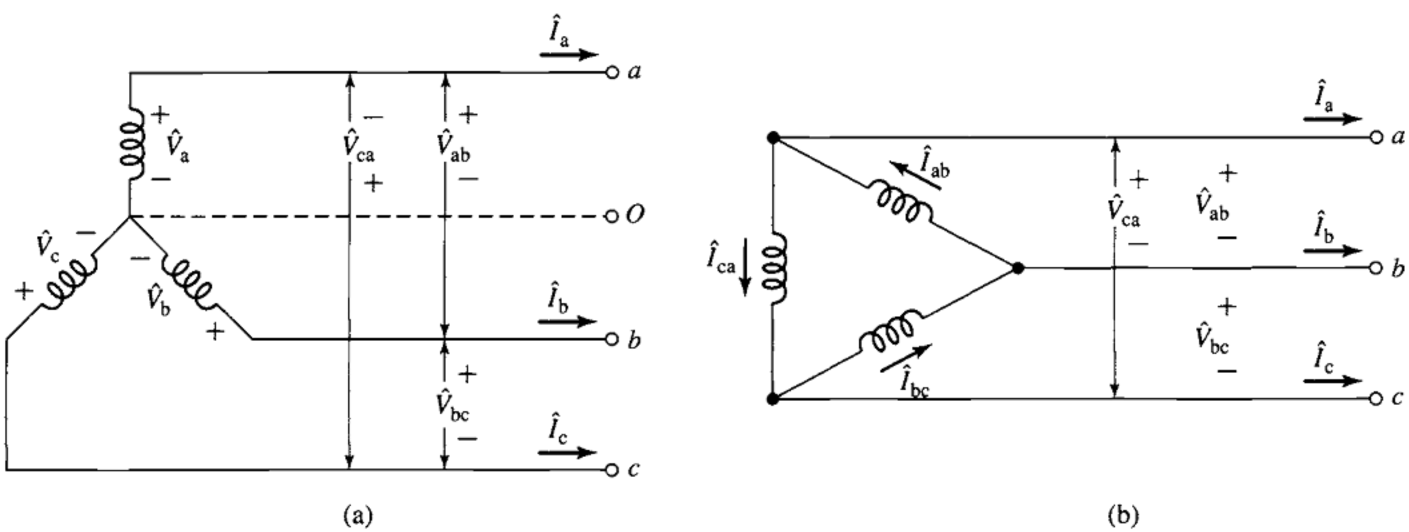


Figure A.5 Three-phase connections: (a) Y connection and (b) Δ connection.

$$\hat{V}_{ab} = \hat{V}_a - \hat{V}_b = \sqrt{3}\,\hat{V}_a \angle 30^\circ \qquad \hat{V}_{bc} = \sqrt{3}\,\hat{V}_b \angle 30^\circ \qquad \hat{V}_{ca} = \sqrt{3}\,\hat{V}_c \angle 30^\circ$$

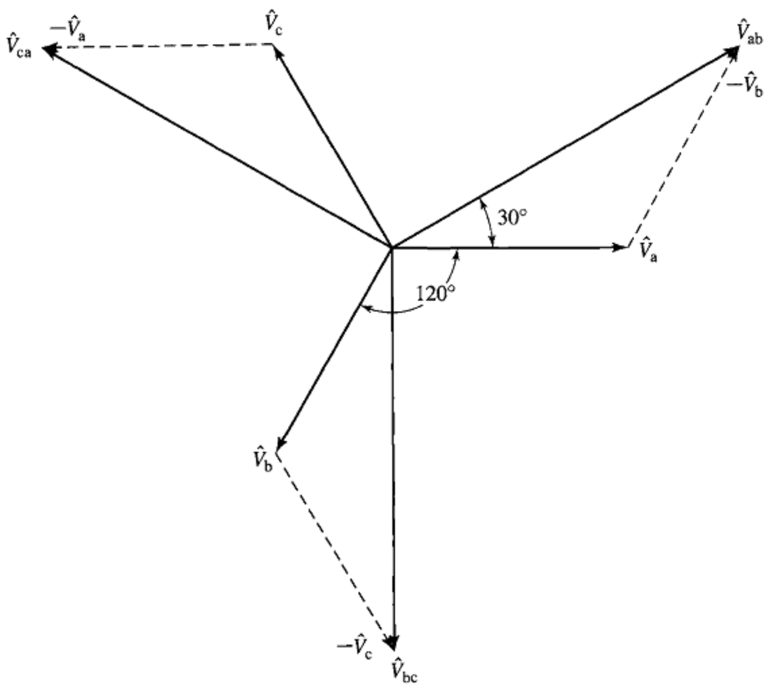


Figure A.6 Voltage phasor diagram for a Y-connected system.

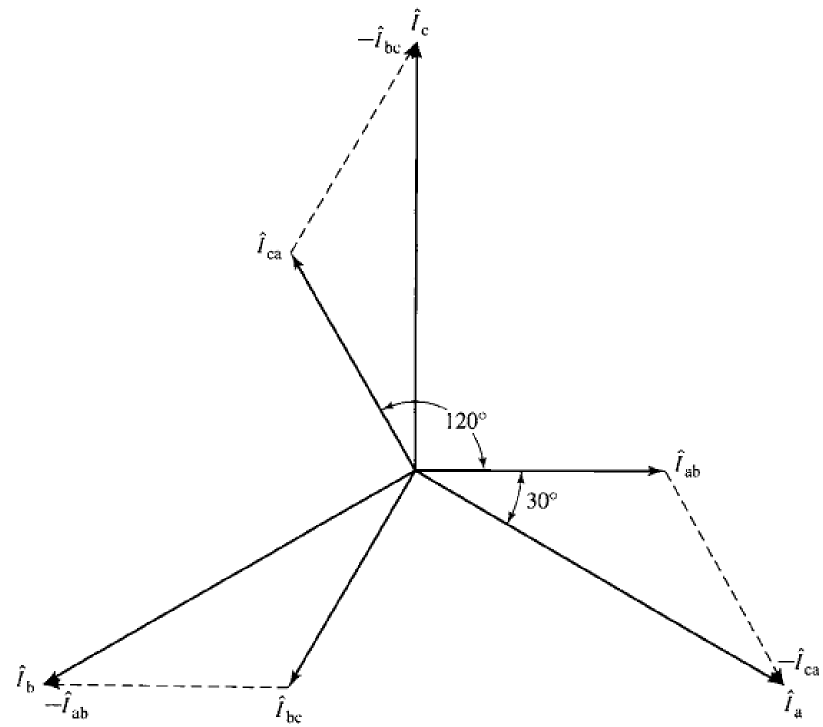


Figure A.7 Current phasor diagram for Δ connection.

$$\hat{I}_a = \hat{I}_{ab} - \hat{I}_{ca} = \sqrt{3}\,\hat{I}_{ab} \angle -30^\circ \qquad \hat{I}_b = \sqrt{3}\,\hat{I}_{bc} \angle -30^\circ \qquad \hat{I}_c = \sqrt{3}\,\hat{I}_{ca} \angle -30^\circ$$

$$v_a(t) = \sqrt{2}\, V_{rms} \cos \omega t \qquad i_a(t) = \sqrt{2}\, I_{rms} \cos(\omega t + \theta)$$

$$v_b(t) = \sqrt{2}\, V_{rms} \cos(\omega t - 120°) \qquad i_b(t) = \sqrt{2}\, I_{rms} \cos(\omega t + \theta - 120°)$$

$$v_c(t) = \sqrt{2}\, V_{rms} \cos(\omega t + 120°) \qquad i_c(t) = \sqrt{2}\, I_{rms} \cos(\omega t + \theta + 120°)$$

$$p_a(t) = v_a(t) i_a(t) = V_{rms} I_{rms}[\cos(2\omega t + \theta) + \cos\theta]$$

$$p_b(t) = v_b(t) i_b(t) = V_{rms} I_{rms}[\cos(2\omega t + \theta - 240°) + \cos\theta]$$

$$p_c(t) = v_c(t) i_c(t) = V_{rms} I_{rms}[\cos(2\omega t + \theta + 240°) + \cos\theta]$$

Note that the average power of each phase is equal

$$< p_a(t) > = < p_b(t) > = < p_c(t) > = V_{rms} I_{rms} \cos\theta$$

The total instantaneous power for all three phases is

$$p(t) = p_a(t) + p_b(t) + p_c(t) = 3 V_{rms} I_{rms} \cos\theta$$

$$Q_p = V_{rms} I_{rms} \sin\theta \qquad Q = 3 Q_p$$

The voltamperes per phase $(VA)_p$ and total three-phase voltamperes VA are

$$(VA)_p = V_{rms} I_{rms} = I_{rms}^2 Z_p \tag{A.22}$$

$$VA = 3(VA)_p \tag{A.23}$$

Balanced three-phase circuits: single-line diagrams

$$P = 3P_p = 3V_pI_p\cos\theta$$

Since $V_{l-l} = \sqrt{3}V_p$, Eq. A.26 becomes

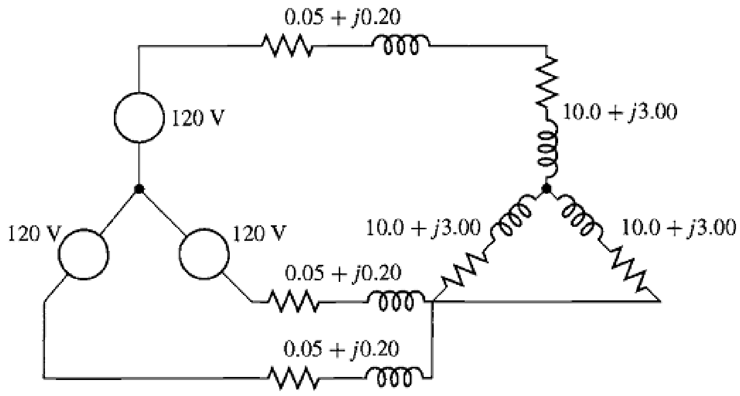
$$P = \sqrt{3}V_{l-l}I_p\cos\theta$$

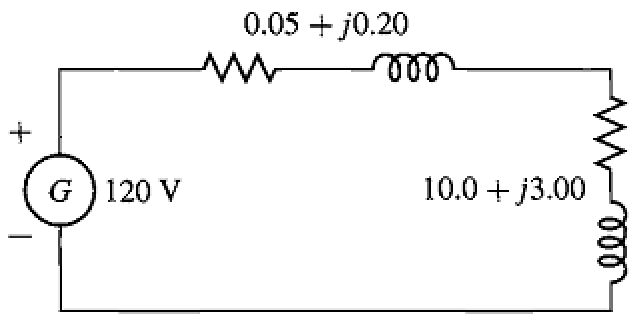
Similarly,

$$Q = \sqrt{3}V_{l-l}I_p\sin\theta$$

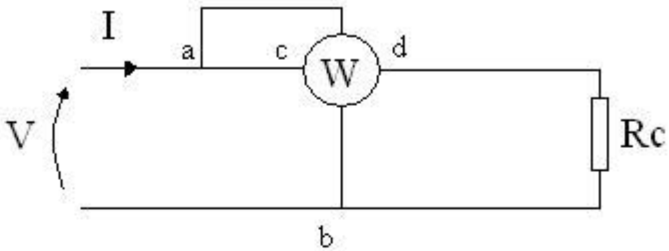
and

$$\mathrm{VA} = \sqrt{3}V_{l-l}I_p$$

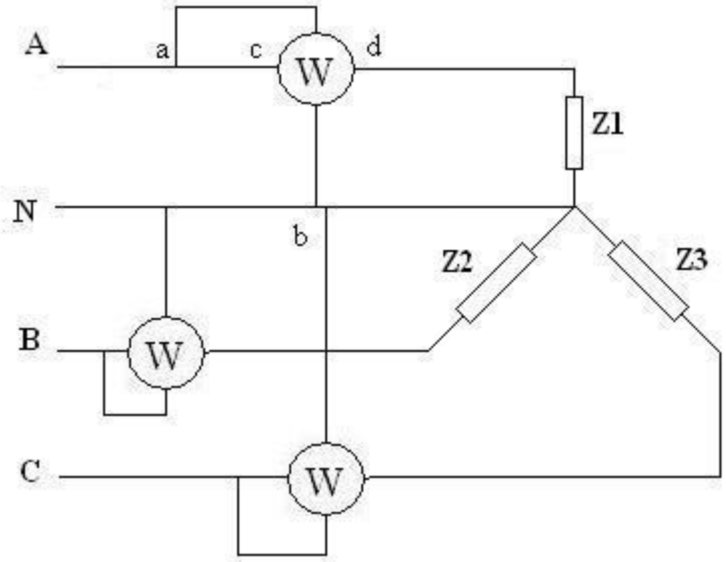




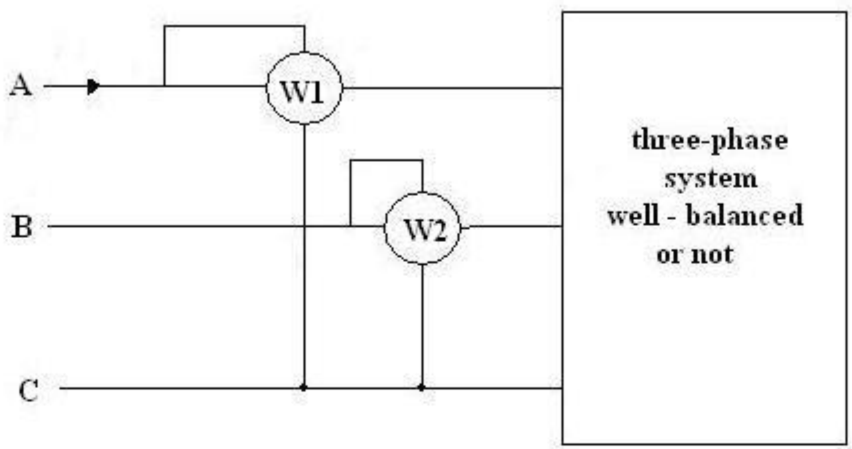
Aron connection



Single-phase wattmeter



Three-phase wattmeter



Aron connection