OC Test/SC Test

$S^2 = P^2 + Q^2$

$S = VI^*$

$Q = \sqrt{S^2 - P^2}$

OC: $X_m = \frac{V^2}{Q}$ ~LV

$R_m = \frac{V^2}{P}$

SC: $X_{eq} = \frac{Q}{I^2}$ ~HV

$R_{eq} = \frac{P}{I^2}$

$pf = \cos(\Theta_{sc}) = \frac{P_{sc}}{V_{sc} I_{sc}} = \frac{P}{S}$

core loss $= P_{oc} = P_c$

copper loss $= P_{sc} = P_{cu} = I^2 R_{eq}$

Max power at $P_c = P_{cu}$

$\eta = \frac{P_{out}}{P_{in}} = \frac{S pf}{S \cdot pf + P_c + P_{cu}}$

PU

$P_{base} = Q_{base} = VA_{base}$

V_{base}

$Z_{base} = \frac{V_{base}^2}{VA_{base}}$

$I_{base} = \frac{VA_{base}}{V_{base}}$

$X_{new} = X_{old} \left(\frac{MVA_{new}}{MVA_{old}}\right) \left(\frac{kV_{old}}{kV_{new}}\right)^2$

$E_a = K_a \phi \omega_m$

$T_e = K_a \phi I_a$

$P_{em} = E_a I_a = T_e \omega_m$

$\omega_m = \frac{V_t - I_a R_a}{K_a \phi}$

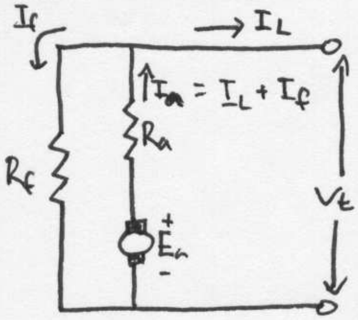
$T_e = \frac{E_a I_a}{\omega_m}$

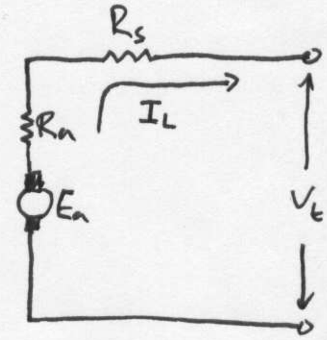
$T_e = K I_a^2$

$V_t - I_a R_a = K I_a \omega_m$

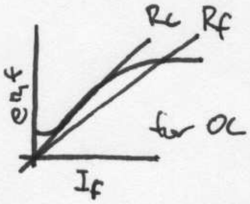
$V_t = I_a (K \omega_m + R_a)$

DC Machines





$V_f = I_f R_f$, $V_t = E_a \pm I_a R_a$ (Motor/Gen)



Starting: → find E_a for FL

→ find $K_a \phi$ for FL

→ $I = \frac{V_t - E_{a,curr}}{R_a + R_{starting}}$

→ $E_a = V_t - (R_a + R_{starting})$(Switched out I)

→ find new ω_m

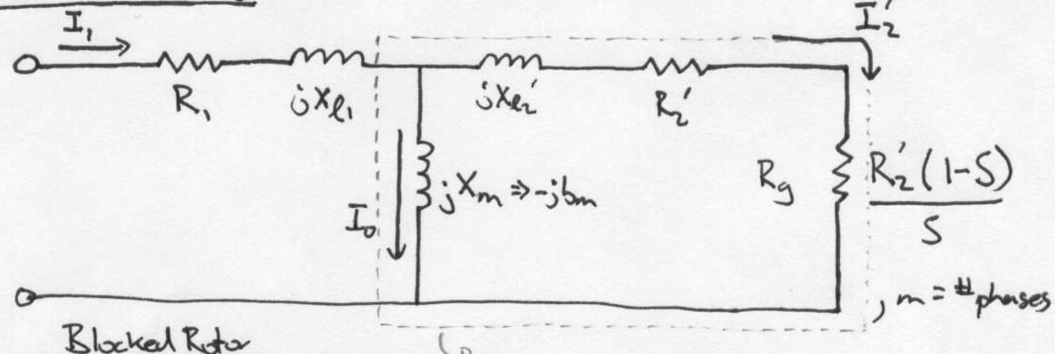
#

$VR = \frac{V_1 - V_2'}{V_2'}$

$\eta = \frac{n \cdot S \cdot pf}{n \cdot S \cdot pf + n^2 P_{cuFL} + P_{core}}$

$n =$ load $(0 \rightarrow 1)$

Induction Machines



, $m = $ # phases

No-load

$R_0 = R_1 + R_m = P_0 / I_0^2$

$Z_0 = V_0 / I_0$

$X_0 = X_{\ell 1} + X_m = \sqrt{Z_0^2 - R_0^2}$

No-load $pf = \cos\phi_0 = P_0 / V_0 I_0$

given $V_L, I_L, P_{3\phi}$

$\rightarrow V_0, I_0, P_\phi$

get $\rightarrow Z_0, R_0, X_0, R_m$

Blocked Rotor

$R_{eq} = R_1 + R_2'' = P_s / I_s^2$

$Z_{eq} = V_s / I_s$

$X_{eq} = X_{\ell 1} + X_2'' = \sqrt{Z_{eq}^2 - R_{eq}}$

Blocked $pf = \cos\phi_s = P_s / V_s I_s$

given $V_L, I_L, P_{3\phi}$

$\rightarrow V_s, I_s, P_s$

$R_2' = \underbrace{(R_{eq} - R_1)}_{R_2''} \frac{(X_{\ell 2}' + X_m)^2}{X_m^2}$

$X_{\ell 1} = X_{\ell 2}' = X_{eq}/2$

$X_m = X_0 - X_{\ell 1}$

for motor, $S = 0 \rightarrow 1$

gen, $S = 1 \rightarrow$

R_f = everything in ⬚

$Z_t = R_1 + jX_{\ell 1} + R_f$, $\measuredangle = pf$

$I_1 = V_{in\phi} / Z_t$

only magnitude! only real!

$$P_g = m\,(I_2')^2 \frac{R_2'}{S} = m\, I_1^2 R_f$$

$P_m = P_g(1-S)$

$$P_{rot} = m\left[P_{in\phi} - \underbrace{I_1^2 R_1 \text{ from NL cond.}}_{\text{stator copper loss}}\right]$$

$P_{out} = P_m - P_{rot}$

$P_{out} = T_{out}\,\omega_m$, $\omega_m = \omega_s(1-S)$

$$T_{out} = \frac{P_{out}}{\omega_s(1-S)} \qquad \omega_s = \frac{2\pi f}{\#\text{poles}/2}, \quad T_{out} = \frac{I_2'^2 R_2'}{s\,\omega_s}$$

, slip at start = 1

$P_{in} = \sqrt{3}\,|V_L||I_L|\,(pf)$

$$V_{1a} = V_1 - I_0(R_1 + jX_{\ell 1}) = V_1 \frac{jX_m}{R_1 + j(X_{\ell 1} + X_m)}$$

$$R_1'' + jX_1'' = \frac{(R_1 + jX_{\ell 1})\,jX_m}{R_1 + j(X_{\ell 1} + X_m)}$$

$$S_{maxT} = \frac{R_2'}{\sqrt{(R_1'')^2 + (X_1'' + X_{\ell 2}')^2}}$$

$$T_{max} = \frac{1}{\omega_s}\,\frac{(0.5)\,m\,(V_{1a})^2}{\sqrt{(R_1'')^2 + (X_1'' + X_{\ell 2}')^2}}$$

$$\frac{T}{T_{max}} = \frac{2}{(S/S_{maxT}) + (S_{maxT}/S)}$$

$E_{rms} = 4.44 f N\phi$, ϕ const!, $E_{rms} \propto f$

slip speed = $\omega_s - \omega_m = s\omega_s$

Swinburne's test

Shunt motor

$$\eta_m = 1 - \frac{V_t(I_f + I_a) + I_a^2 R_a}{V_t(I_f + I_a)}$$

Shunt gen

$$\eta_g = 1 - \frac{V_t(I_f + I_a) + I_a^2 R_a}{V_t(I_f + I_a) + I_a^2 R_a}$$

Kapp-Hopkins

generator input = motor output = η(motor input)

$= \eta\,(V_t I_a)$

generator output = $V I_B = \eta$ (gen. input) $= \eta^2 V I_a$

$\eta = \sqrt{I_B / I_a}$

$P = V I_L - (I_a^2 R_a - I_B^2 R_B)$

$$\eta_m = 1 - \frac{P/2 + I_a^2 R_a + V I_a}{V(I_a + I_{fa})}$$

$$\eta_g = 1 - \frac{P/2 + I_B^2 R_B + V I_{fB}}{V(I_B - I_{fB}) + P/2 + I_B^2 R_B}$$

$I_2' \propto V_1$

$$\frac{I_2' \text{ reduced voltage}}{I_2' \text{ full-load voltage at starting}} = k$$

$\therefore I_2'$ red voltage $= k\,(I_2')_{FL \text{ voltage at starting}}$

$$V_{X\,Hz} = V_{Y\,Hz}\,\frac{X_{Hz}}{Y_{Hz}}$$