Ex Synchronous machine, motor $f = 60\,Hz$

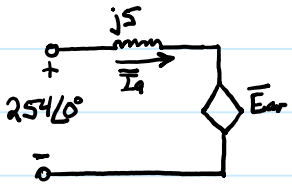
$X_s = 5\,\Omega/phase$

$PF = 0.8$ leading

$I_a = 30\,A$

$V_a = 254\,V$

$P_{loss} = 400\,W$



$\theta = -\cos^{-1}(PF) \Rightarrow \theta = -36.87°$

$\bar{I}_a = 30\angle 36.87°\,A$

$\bar{E}_{ar} = 254\angle 0° - j5(30\angle 36.87)$

$= 254\angle 0° - (5)(30)\angle 90 + 36.87$

$= 254 - (-90 + j120)$

$= 344 - j120$

$\bar{E}_{ar} = 364.3\angle -19.23°\,V$

$\bar{E}_{ar} = E_{ar}\angle \delta$

δ is torque angle

$P_T = 3Re\{\bar{E}_{ar}\bar{I}_a^*\} = 3Re\{(364.3\angle -19.23)(30\angle -36.87)\}$

$= 3Re\{10929\angle -56.1\}$

$P_T = 18{,}286.8\,W$

$T^e = \frac{P_T}{\omega_m} \Rightarrow T^e = \frac{18{,}286.8}{377} \Rightarrow T^e = 48.51\,N_m$

$P_{shaft} = P_T - P_{loss} \Rightarrow P_{shaft} = 17{,}886.7\,W$

$\eta = \frac{P_{shaft}}{P_T} \Rightarrow \eta = 97.8\%$

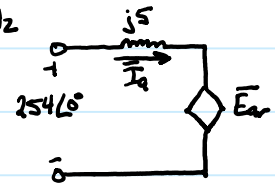
Ex Synchronous machine, motor $f = 60\,Hz$

$V_a = 254\,V$

$X_s = 5\,\Omega$

$PF = 0.9$ lag

$I_a = 30\,A$



$\theta = \cos^{-1}(PF) \Rightarrow \theta = 36.87$

$\boxed{\bar{I}_a = 30\angle -36.87°\,A}$

$\bar{E}_{ar} = 254\angle 0° - j5(30\angle -36.87°)$

$= 254\angle 0° - 150\angle 53.13°$

$= 254 + j0 - (90 + j120)$

$= 164 - j120\,V$

$\boxed{\bar{E}_{ar} = 203.2\angle -36.19°\,V}$ $\quad \delta = -36.19°$

$P_T = 3\,Re\{(203.2\angle -36.19°)(30\angle 36.87°)\} \Rightarrow P_T = 3\,Re\{6096\angle 0.68°\}$

$\boxed{P_T = 18,286.7\,W}$

$P_{shaft} = P_T - P_{loss} \Rightarrow \boxed{P_{shaft} = 17,886.7\,W,\ \eta = 97.8\%}$

$T^e = \frac{P_T}{\omega} \Rightarrow \boxed{T^e = 48.51\,Nm}$

* Note: can also calculate P_T as $P_T = \frac{-3V_a E_{ar}\sin(\delta)}{X_s}$ for motor and

$P_T = \frac{3V_a E_{ar}\sin(\delta)}{X_s}$ for generator

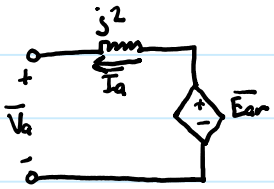
Ex Generator, Synchronous, $f = 60\,Hz$

$X_s = 2\,\Omega$

$V_a = 1905\,V$

$I_a = 350\,A$

$PF = 0.8$ lag



$\theta = \cos^{-1}(PF) \Rightarrow \theta = 36.87°$

$\boxed{\bar{I}_a = 350\angle -36.87°\,A}$

$\bar{E}_{ar} = 1905\angle 0° + j2(350\angle -36.87°)$

$= 1905 + (420 + j560)$

$= 2325 + j560$

$\boxed{\bar{E}_{ar} = 2391.5\angle 13.54°\,V}$ $\quad \delta = 13.54°$

$P_T = 3Re\{2391.5\angle 13.54°(350\angle 36.87°)^*\}$

$P_T = 3Re\{837025\angle 50.41°\}$

$\boxed{P_T = 1.6\,MW}$

$T^e = \frac{P_T}{\omega}$

$\boxed{T^e = 4244\,Nm}$

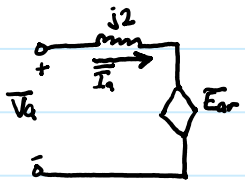
Ex 3phase, 6 pole, synchronous motor $f = 60Hz$

$X_s = 2\Omega$

$V_L = 230V$

PF = 0.85 lead

$I_a = 50A$



$\omega_m = \frac{2}{p}\omega_s \Rightarrow \omega_m = \frac{1}{3}(377)$ $\quad RPM = \frac{\omega}{2\pi} \cdot \frac{60s}{1min} \Rightarrow \boxed{RPM = 1200}$

$\bar{V}_a = \frac{V_L}{\sqrt{3}}\angle 0° \Rightarrow \bar{V}_a = 132.8\angle 0° V$

$\bar{I}_a = 50\angle 31.79°$

$\bar{E}_{ar} = 132.8\angle 0° - j2(50\angle 31.79°)$

$\bar{E}_{ar} = 132.8 - (-52.68 + j85)$

$\boxed{\bar{E}_{ar} = 204\angle -24.6° V}$

$E_{ar} = 204V, \ \delta = -24.6°$

$\bar{S}_T = 3\bar{V}_a\bar{I}_a^*$

$\bar{S}_T = 19,920\angle 31.79°$

$\boxed{\bar{S}_T = 16931 - j10494 \ VA}$

$P_T = 16931 W$

$T^e = \frac{P_T}{\omega_m} \Rightarrow \boxed{T^e = 134.73 Nm}$

$I_r = 20A$ for above.

Find I_r for PF = 1.

$S_T = P_T = 16931 W$

$16931 = 3V_aI_a \Rightarrow I_a = 42.5A$ $\quad \bar{I}_a = 42.5\angle 0° A$

$\bar{E}_{ar} = \bar{V}_a - j2\bar{I}_a$

$= 132.8\angle 0° - 2(42.5)\angle 90°$

$= 132.8 - j85 V$

$\bar{E}_{ar} = 157.67\angle -32.62 V$

$\frac{E_{ar_1}}{I_{r_1}} = \frac{E_{ar_2}}{I_{r_2}}$

$I_{r_2} = \left(\frac{E_{ar_2}}{E_{ar_1}}\right) I_{r_1}$

$\boxed{I_{r_2} = 15.45A}$