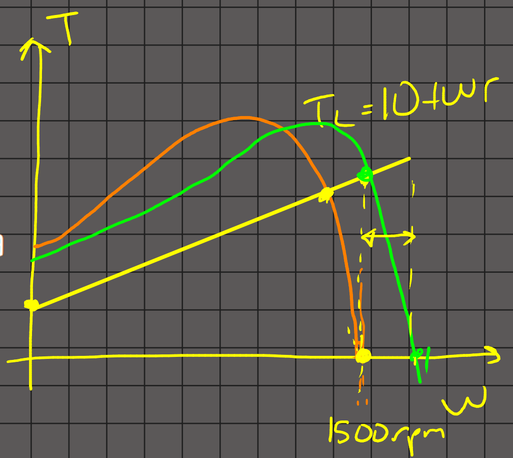
A 380 V(l-l) 3-phase 4-pole Y-connected induction motor's torque-speed characteristics can be approximated as:

$N_{syn} = 1500\,rpm$

$$T_m = ks = \frac{3V^2}{r_2'\omega_s}s$$



where $r_2' = 1\Omega$/phase. The motor is used to drive a load at a precisely constant speed of 1500 rpm. The load torque can be expressed as:

$$T_L = \omega_r + 10 \text{ Nm.}$$

a) Propose a method of speed control for this purpose and explain your reasoning, and calculate the required controller parameters.

Variable frequency (VFD) drive
→ Constant (V/f) operations

b) Calculate the operating slip of the motor.

c) Give a rough estimate for the efficiency of the motor under these conditions.

d) What is the minimum value of starting torque the motor must produce?

b) Slip=?

$N_r = 1500\,rpm \Rightarrow \omega_r = \frac{1500}{60} \cdot 2\pi = 157\,rad/s \leftarrow \omega_s.$

$T_L = 157 + 10 = 167\,Nm$

↳ Steady-state ⇒ $T_e = T_L$

$$T_e = \frac{3V_1^2}{\omega_s \cdot r_2'} \cdot s \Rightarrow 167 = \frac{3 \cdot \left(\frac{220}{50\pi} \cdot \omega_s\right)^2}{\omega_s \cdot \cancel{r_2'}} \cdot s$$

V_1	f	ω_s ← mech. synch. speed
$380/\sqrt{3} = 220V$ →	50Hz	50π
$4.4 f_e$	f_e	
$\left(\frac{220}{50\pi} \cdot \omega_s\right)$		(ω_s)

$$167 = 3\left(\frac{220}{50\pi}\right)^2 \cdot W_s \cdot S \Rightarrow 167 = 3\cdot\left(\frac{220}{50\pi}\right)^2 \cdot \cancel{W_s} \cdot \frac{(w_s - w_r)}{\cancel{w_s}}$$

$$\frac{W_s - W_r}{w_s} = S$$

w_s ← rotates 1500rpm)

$$\underline{\underline{w_s - w_r = 28{,}4 \text{ rad/s}}}$$

$$w_s = w_r + 28{,}4 \text{ rad/s}$$

$$w_s = \frac{1500}{60} \cdot 2\pi + 28{,}4 = 185{,}5 \text{ rad/s}$$

$$\boxed{f_s = \frac{185{,}5}{2\pi} = \underline{\underline{59 H_z}}}$$

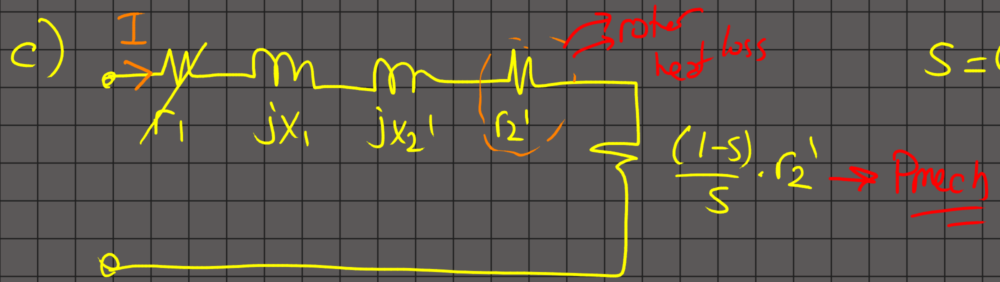
$$V_1 = 4{,}4 \cdot 59$$

$$\underline{\underline{V_1 \cong 260V}}$$

$$\boxed{V_{ll} = 450V}$$

$$S = \frac{w_s - w_r}{w_s} = \frac{28{,}4}{185{,}5} = \underline{\underline{0{,}153}}$$

c)



$S = 0{,}153$

$$\eta = \frac{3I^2 \cdot \left(\frac{1-s}{s}\right) \cdot r_2'}{\underbrace{\cancel{3I^2}\left(\frac{(1-s)}{s} r_2' + r_2'\right)}_{\sim P_{in}}} = \frac{(1-s)/\cancel{s}\, \cancel{r_2'}}{\cancel{r_2'}/\cancel{s}} \cong \underline{\underline{1-s}}$$

$$\eta \cong (1 - 0{,}153) \cong \underline{\underline{84{,}7\%}}$$

d) $T_L = 10 + w_r$

$T_L = 10 Nm$ (@ 0rpm)

$\underline{\underline{T_e > T_L}}$ $\quad$ $\underline{\underline{T_e > 10Nm}}$