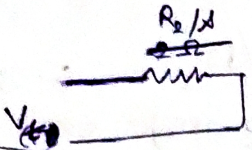
EE238 Assignment - 2

Sol. 1]



440V, 3ϕ, 50Hz, 945rpm
6 pole, Y-connected

$r_1 = 0\Omega \quad r_2' = 2\Omega$
$x_1 = 0\Omega \quad x_2' = 0\Omega$

X_M, rot. losses $= 0$

Rated Torque of motor :

$$T_{rated} = \frac{P_{gap}}{\omega_{synch}} = \frac{3 I_2'^2 (R)}{\omega_s}$$

$$f = 50\,Hz \therefore N_s = \frac{120 \times 50}{6} = 1000\ rpm$$

$$\therefore s_{rated} = \frac{1000 - 945}{1000} = 0.055$$

Now, given T_L is INDEPENDENT of speed

$$\therefore T_L = \frac{3}{\omega_s}\left[\frac{V_t}{(r_2'/s)}\right]^2 (r_2'/s) = \text{CONST}$$

$$\Rightarrow sV_t^2 = \text{CONST} \quad , \Rightarrow s_{rated}(V_{t_{rated}})^2 = s V_t^2$$

$$s = \frac{1000 - 800}{1000} = 0.2$$

$$\therefore (0.055)\left(\frac{440}{\sqrt{3}}\right)^2 = 0.2\, V_t^2$$

$$\Rightarrow V_t\Big|_{800rpm} = 133.2166\,V_{(L-N)}$$

$$\therefore \boxed{(V_t)_{LL} = 230.73\,V}$$

ii) Given that freq = 50Hz $\longrightarrow$ Kept ~~const~~ CONST
and that now required N_r = 800 rpm,

$\therefore$ slip has to be $\frac{1000-800}{1000} = 0.2$

and we just calculated that V_t required to acquire a slip of 0.2 at rated conditions to be $V_t = 133.21V$

$$\left(\text{from } 3 \times \frac{1}{\omega_s} \times \left(\frac{V_t^2}{r_2/s}\right) = \text{rated Torque} = \frac{3}{\omega_s}\frac{(440/\sqrt{3})^2}{(R_2/0.055)}\right.$$

$\omega_s = \frac{2\pi}{60}(1000)$, $s \to 0.2$

∴ the current drawn in this case = $\frac{133.21}{2} \times 0.2 = 13.32\,A$.

But ... at rated condition,
$$I_2' = \frac{V_t}{(r_2'/s)} = \frac{440/\sqrt{3}}{(2/0.055)} = 6.99\,A$$

∵ current drawn > rated current, overheating occurs.

Load torque that can be born while drawing rated current (6.99A)

$$T_L = \frac{3}{\left(\frac{2\pi}{60}(1000)\right)} \times (6.99)^2 \times \frac{2\,\Omega}{0.2} = 13.97\,Nm$$

∴ % reduction in T_L reqd = $\frac{50.831 - 13.97}{50.831} \times 100\% = \boxed{72.51\%}$

Now, let the per-phase stator voltage = V.

$$\frac{V}{(r_2'/s)} = 6.99 \Rightarrow \frac{V}{(2/0.2)} = 6.99 \Rightarrow \boxed{V = 69.9\,V}.$$

$$\therefore V_{(L-L)} = \sqrt{3} \times 69.9 \approx \boxed{121\,V}.$$

Sol. 2]

440V, 3φ, 50Hz, 4 pole, 1420 rpm Δ-~~load~~ IM

with $r_1 = 0\,\Omega$, $r_2' = 0.4\,\Omega$, $X_1 = 0\,\Omega$, $X_2' = 0.8\,\Omega$

$\frac{120 \times 50}{4} = 1500$

∴ ~~$s = \frac{1500-1420}{1500}$~~

$\boxed{s = 4/75}$

Let applied voltage → K·440 V and applied freq → K·50 Hz to negotiate CONST $T_L = 485\,Nm$, ∵ the motor is fed from VSI at rated values

~~$\therefore \frac{3}{\left[\frac{2\pi}{60}(1500)\right]} \times \frac{(440)^2}{(0.8)^2 + \left(\frac{0.4}{(4/75)K}\right)^2} \times \frac{0.4}{(4/75) \times K} = 485$~~

$$\Rightarrow \frac{3}{157.08} \cdot \frac{440^2}{(0.8)^2 + \left(\frac{0.4}{sK}\right)^2} \times \frac{0.4}{sK} = 485$$

$$\Rightarrow 0.21\,(sK)^2 - sK + 0.05 = 0$$

$$\Rightarrow sK = 0.05,\ \cancel{4.71}$$

Now, $s = \frac{K1500 - 700}{K1500}$

$$\Rightarrow sK = \left(\frac{K \cdot 1500 - 700}{1500}\right) = 0.05$$

$K \cdot 7500 = 700 + 75 \Rightarrow K = 0.516$

$\therefore V_t$ applied $= K \cdot \cancel{4440}0 = \boxed{227.04V}$ $\quad f_{rated} = 0.516 \times 50Hz = \boxed{25.8 Hz}$

Sol. 3] Rated slip $= \dfrac{1500 - 1420}{1500} = 0.05$ ~~Rated~~

Rated current $= \dfrac{440}{\sqrt{\left(\frac{0.4}{0.05}\right)^2 + \cancel{(0.8)^2}}} = \dfrac{440}{0.4} \times 0.05 = \underline{55A}$.

$\therefore$ Rated Torque $= \dfrac{3}{\left[\frac{2\pi}{60}(1500)\right]} \times 55^2 \times \dfrac{0.4}{0.05} = 462.2$ Nm

$\therefore \frac{1}{2}$ rated Torque $= 231.1$ Nm

$\because$ given the m/c is operating in 4^{th} Quadrant $\Rightarrow T_L$ +ve, speed -ve.

$\therefore \dfrac{3}{157.07} \cdot \dfrac{440^2}{0.4} sK = 231.10 \Rightarrow \underline{sK = 0.024}$

Now, $s = \dfrac{K \cdot 1500 - (-1500)}{K1500} \Rightarrow sK = \dfrac{K \cdot 1500 + 1500}{1500} = 0.024$

$\Rightarrow K + 1 = 0.024 \Rightarrow K = -0.976$ means phase sequence of voltage has been reversed.

$\therefore$ applied voltage $= 440 \times 0.976 = \boxed{429.44V}$

" freq $= 50 \times 0.976 = \boxed{48.8Hz}$

implies that its current synch speed $= \dfrac{120 \times 48.8}{4} = 1464$ rpm

m/c in braking mode. $\Leftarrow$ < 1500 rpm (machine speed

Sol.4] EV: 3ϕ inverter-fed 440V, 50Hz, 3ϕ, 4pole, 1420 rpm, Δ - IM with $r_1 = 0$, $r_2' = 0.4\Omega$, $X_1 = 0\Omega$, $X_2' = 0\Omega$ → controlled by V-f method.

$$\therefore \text{rated Torque} = \frac{3}{\left[\frac{2\pi}{60}(1500)\right]} \times \frac{440^2}{0.4} \times \frac{(1500-1420)}{1500}$$

$$= \frac{3}{157.07} \times 55^2 \times \frac{0.4}{0.05} \simeq 462.2 \text{ Nm}$$

$\therefore \frac{1}{4}$th rated torque $\simeq 115.6$ Nm, $\frac{1}{2}$ rated Torque $= 231.1$ Nm

a) $\omega_r = 2000$ rpm → above base speed!

$\therefore$ for speeds above base speed, $V = V_{rated}$, $f = kf_{rated}$

$$\omega_s = \frac{N_s \times \frac{2\pi}{60}}{(1-s)}$$

$$\therefore 115.6 = \frac{3}{\left[\frac{\left[\frac{2\pi}{60}(2000)\right]}{(1-s)}\right]} \times \left[\frac{440^2}{\left(\frac{0.4}{s}\right)}\right] = \frac{3 \times 30 \times 440^2}{2000\pi \times 0.4} s(1-s)$$

$\Rightarrow 0.015 = s - s^2 \Rightarrow s = 0.015$, $\cancel{0.99}$

$s' = 0.015 \Rightarrow N_s' = 2030$ rpm

$= \frac{N_s' - N_r}{N_s'}$ $\quad f' = 50.8$ Hz

b) breaking Torque $= \frac{1}{2} T_{rated}$

$$\Rightarrow \frac{3}{\frac{\omega_s}{(1-s')}} \times \frac{V_t^2}{(r_2'/s')} = 231.1 \text{ Nm} \Rightarrow s'^2 - s' + 0.0265 = 0$$

$s' = 0.027$

$$\therefore \omega_s = \frac{2000}{(1-s)} \simeq 2055 \text{ rpm}$$

$\therefore$ current synch. speed for $-$ve T with $\omega_r = 2000$ rpm

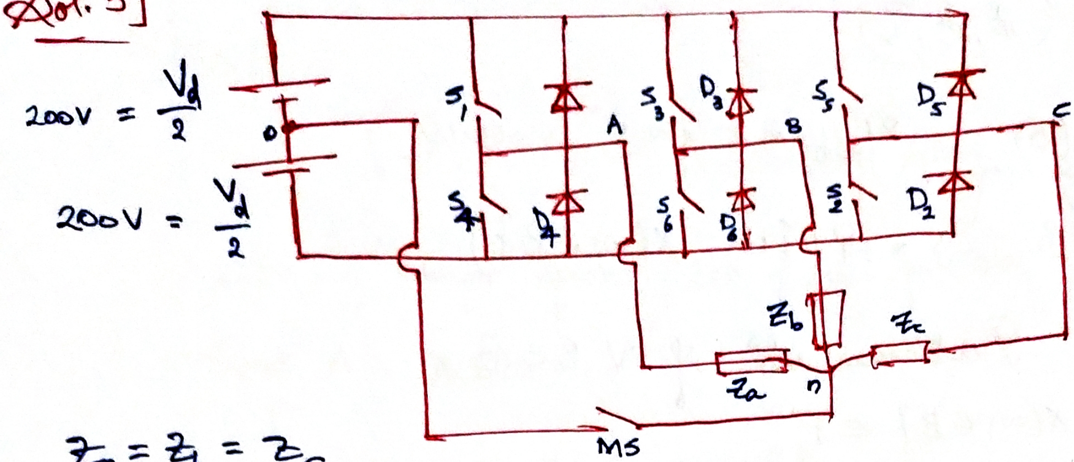
$= 2000 - 55 = 1945$ rpm

$$\therefore k = \frac{1945}{1500} \simeq 1.296$$

$\therefore$ $\boxed{V = 440V}$

$\boxed{f = 64.8 \text{ Hz}}$

Sol. 5]



$Z_a = Z_b = Z_c$

[BALANCED]

$V_{ctr} = 0.5V$ $\quad f_{ctr} = 25Hz$ $\quad V_{tri} = 1V$ $\quad f_{tri} = 2625Hz$

SPWM

$\therefore \quad m_a = \frac{0.5}{1} = 0.5$ and $m_f = \frac{2625}{25} = 105$.

$\Rightarrow (\hat{V}_{AO})_1 = m_a \cdot \frac{V_d}{2} = 0.5 \times \frac{400}{2} = 100V$:

$\therefore (\hat{V}_{AB})_1 = (\hat{V}_{AO})_1 \cdot \sqrt{3} = 173.2V$.

Now, SPWM $\rightarrow$ Harmonic spectrums : $f_h = (jm_f \pm k) f_1$

$h = j(m_f) \pm k$

* If j is odd, $k \rightarrow$ even.