EEE4117F: ONLINE QUIZ 2

ELECTRICAL MACHINES AND POWER ELECTRONICS

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PART A – ELECTRICAL MACHINES

Question 1:

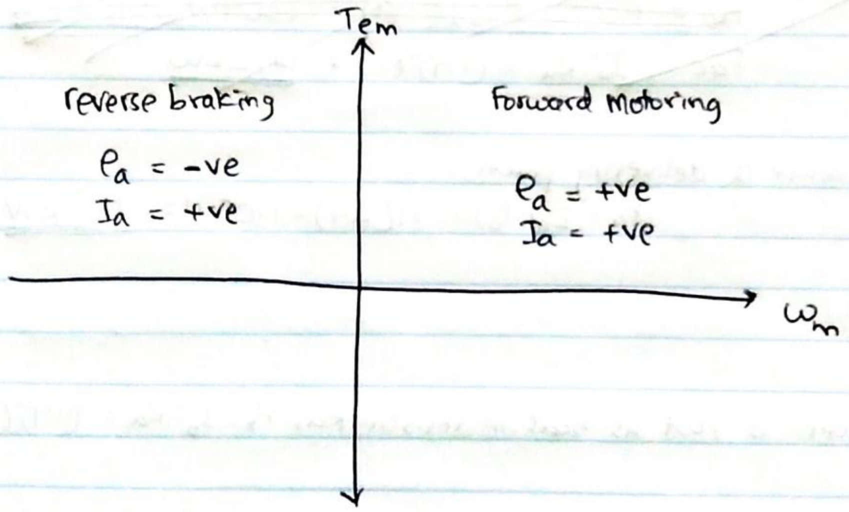
Part A: Question 1:

1.1> A ~~self~~ separately excited DC motor is Ideal for this application as ~~to~~ the rated speed is quiet high at 5000rpm and we want to alter the speed as well to 1000rpm.

1.2> a> It helps to provide flexibility in speed Control
b> It provides a quick response and regeneration to very low speeds.

⇒ Class B chopper is Used.

1.3>



Question 2:

Part A: Question 2:

2.1) Initial Conditions: $V_t = 220V$, $\omega = 960rpm$, $I_a = 80A$, $R_a = 0.06\,\Omega$

@ initial condition of $\omega = 960rpm$:

$$V_t = E_a + I_a R_a$$

$$220 = E_a + 80(0.06)$$

$$\underline{E_a = 215.2V}$$

Now:

@ $\omega_1 = 620rpm$:

$$\frac{E_{a_1}}{E_a} = \frac{\omega_1}{\omega} = \frac{620rpm}{960rpm}$$

$$E_{a_1} = \frac{620}{960} * 215.2 = \underline{138.98V}$$

Thus: $V_t = E_{a_1} + I_a R_a$

$$V_t = 138.98 + 80(0.06) = 143.78V$$

$$\therefore \boxed{V_t = 143.78V}$$

2.2) As ω increases from base speed, E_a remains constant

$$E_{a_2} = E_{a_1}$$

$$K_e \phi_2 \omega_2 = K_e \phi_1 \omega_1$$

$$\phi_2 \omega_2 = \phi_1 \omega_1$$

$$\phi_2 = \frac{\phi_1 \omega_1}{\omega_2} = \phi_1 * \frac{960rpm}{1200rpm}$$

$$\phi_2 = 0.8\phi_1$$

$$\phi_2 = (80\%)\phi_1$$

$$\therefore \boxed{\phi_2 = (80\%)\phi_1}$$

Part A:

2.3) Again, as ω increases from base speed, I_a is constant:

$$\cancel{T_{e_2} = T_{e_1}}$$
$$\cancel{k_e\phi_2 I_{a_2} = k_e\phi_1 I_{a_1}}$$
$$\cancel{\phi_2 = \phi_1}$$

$$T_{e_1} = k_e\phi_1 I_{a_1} \quad ; \quad T_{e_2} = k_e\phi_2 I_{a_2}$$

$$\frac{T_{e_1}}{T_{e_2}} = \frac{\phi_1}{\phi_2} = \frac{\omega_2}{\omega_1} = \frac{1200\,rpm}{960\,rpm}$$

$$T_{e_2} = \frac{T_{e_1} * 960\,rpm}{1200\,rpm}$$

but: $T_{e_1} = \frac{P}{\omega_1} = \frac{E_a I_a}{\omega_1} \longrightarrow$ $$T_{e_2} = \left[\frac{E_a I_a}{\omega_1}\right] * \frac{960\,rpm}{1200\,rpm}$$

$$T_{e_2} = \left[\frac{(215.2)(80)}{\left(960 \times \frac{2\pi}{60}\right)}\right] * \frac{960}{1200}$$

$$\boxed{T_{e_2} = 137\ N_m}$$

2.4) Rated Power $= V_{rated} * I_{rated} = 220(80) = \underline{\underline{17.6kW}}$

$$\text{Rated Torque, } T_r = \frac{P_r}{\omega} = \frac{17.6kW}{\left(960 * \frac{2\pi}{60}\right)} = \underline{175.07Nm}$$

$$\text{P-P ripple torque} = 0.02 * T_r = 0.02 * (175.07) = \underline{\underline{3.501N_m}}$$

$$\therefore \boxed{\text{P-P ripple torque} = 3.501\ Nm}$$

2.5) @ $\omega = 960rpm$:

$$V_t = E_a + I_a R_a$$

$$220 = E_a + 80(0.06)$$

$$E_a = 215.2V$$

@ $\omega = 300rpm$:

$$\frac{E_{a_1}}{E_a} = \frac{\omega_1}{\omega} = \frac{300rpm}{960rpm}$$

$$E_{a_1} = \frac{300}{960} \times 215.2 = 67.25V$$

$$R_a + R_b = \frac{E_{a_1}}{2I_a} = \frac{67.25}{2(80)} = 0.4203\Omega$$

$$R_b = 0.4203\Omega - R_a = 0.4203\Omega - 0.06\Omega = 0.3603\Omega$$

$$\therefore \boxed{R_b = 0.3603\Omega}$$

2.6) $f = 1kHz$; $L_a = 5mH$

$$T = \frac{1}{f} = \frac{1}{1kHz} = 1ms$$

$$D = \frac{t_{on}}{T} \Rightarrow t_{on} = D.T = 0.5 * 1ms = 0.5ms$$

$$\boxed{t_{on} = 0.5ms}$$

$$\tau_a = \frac{L_a}{R_a} = \frac{5mH}{0.06\Omega} = 0.083 \ H/\Omega$$

$$\boxed{\tau_a = 0.083 \ H/\Omega}$$

2.7) If $f = 4kHz$; $T = 0.25ms$; $t_{on} = 0.125ms$ and $L_a = 20mH$; $\tau_a = 0.333 \ H/\Omega$

Thus; armature current ripple will increase and the losses in the DC motor drive will also increase due to increase of ripple current.

PART B – POWER ELECTRONICS

Question 1:

Part B: Question 1:

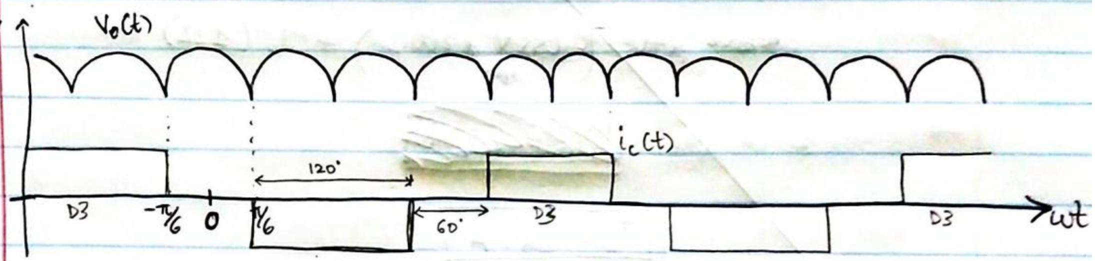
1.1> $V_{aB} = V_{aN} - V_{BN}$

∴ $\boxed{V_{BN} = V_{aN} - V_{aB}}$

$V_{BC} = V_{BN} - V_{CN}$

∴ $\boxed{V_{CN} = V_{BN} - V_{BC}}$

1.2>



1.3> $$V_o(t) = \frac{1}{\pi/3}\int_{-\pi/6}^{\pi/6} \sqrt{2}\, V_{LL} \cos(\omega t)\, d(\omega t)$$

∴ $V_o(t) = 1.35\, V_{LL} = 1.35\, V_{ab} = 1.35\,(V_r - V_{r_b})$

$\cancel{V_o(t) = V_{ab} = \sqrt{2}\, V_{LL} \cos \omega t}$

1.4>

(a) $100\sqrt{2}$

(b) $100\sqrt{2}$

(c) $200\sqrt{2}$

(d) $400\sqrt{2}$

Question 2:

Part B : Q2:

2.1) $V_d = 0.9 V_s \cos\alpha$

$= 0.9(240)\cos 60°$

$V_d = 108\,V$

$V_d = -E_a + I_o R_a$

$108 = -(0.055 \frac{V}{rpm} * 200 rpm) + I_o(1\Omega)$

$\boxed{I_o = 119\,A}$

2.2) AC supply is ~~delivering~~ receiving power:

$\cancel{P_{ac} = E_a(I_o) = 11(119) = 1309W = 1.31kW}$

$\cancel{P_{ac} = I_o^2 R_a = (119)^2(1) = 14.2kW}$

2.3) DC machine is delivering power:

$P_a = E_a(I_o) = 11(119) = 1309W = 1.31kW$

2.4) All power is lost as heat in resistor Ra. $P_x = I_o^2 R_a = (119)^2(1) = 14.2kW$

2.2) AC supply is receiving power:

$P_{ac} = I_o R_a + E_a I_o = 119(1) + (11)(119)$

$P_{ac} = 1.43kW$

2.5) $S = VI = 240(119) = 28.56kW$

$PF = \frac{P_{ac}}{S} = \frac{1.43kW}{28.56kW} = 0.05$