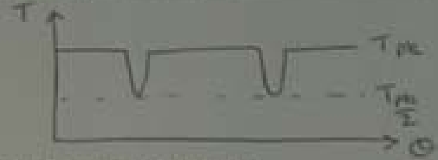
EE4001 Quiz 1: DC Machines

Student Name: **Student Number:**

1. Sketch a plot of torque vs. angle for a primitive two-pole dc motor with an armature winding consisting of 4 coils wave wound.



2. Derive the torque-speed characteristic equation for a dc machine.

$V = E + I_a R_a$

$E = k\Phi\omega$

$T = k\Phi I_a$

$$V = k\Phi\omega + \frac{T}{k\Phi} \cdot R_a$$

$$\omega = \frac{V}{k\Phi} - \frac{R_a}{(k\Phi)^2} T$$

3. A generator develops a back emf of 100 V at 1000 rpm. Under full-load current draw of 10 A, the field flux is weakened by 5 % due to armature reaction. Calculate the full-load terminal voltage when the armature resistance is 0.5 Ω.

$V = E - I_a R_a$ @ 1000rpm, NL $\Rightarrow$ $V \approx E = 100V$

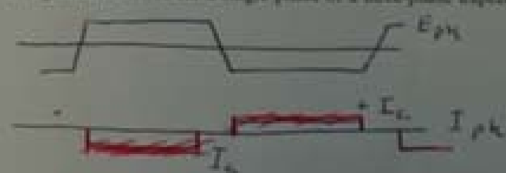
$= k\Phi \cdot \omega - I_a R_a$ @ $I_a = 10A$, 1000rpm

$V' = 0.95E - 10 \times .5 = 90V$

4. A 250 V, 400A compound generator has 1000 shunt-field turns per pole and 3 series-field turns per pole. What is the effective field current when the series-field current is 5 A?

$$I_{f,e} = I_f + \frac{N_{fs}}{N_f} I_a = 5 + \frac{3}{1000} \cdot 400 = 6.2A$$

5. Sketch together the induced emf and phase current in regenerative mode for a single phase of a three-phase trapezoidal-waveform electronically-commutated motor.



6. An EC dc motor is sourced by a 50 V supply, and pulls 10 A from the source. The phase-phase resistance is 0.5 Ω. The output speed is 5000 rpm. What are the output torque and machine efficiency, neglecting core, friction, and windage losses?

$E = V - I_a R_a$

$= 50 - 10 \times 0.5V$

$= 45V$

$EI = T\omega = 450W$

$$T = \frac{EI}{\omega} = \frac{45 \times 10}{5000} \cdot \frac{60}{2\pi} = 0.859 \ Nm$$

$$\eta = \frac{EI}{VI} = \frac{45}{50} = 90\%$$

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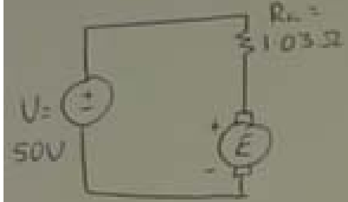
PROBLEM 1: A **permanent-magnet** dc motor is known to have an armature resistance of 1.03 Ω. When operated at no load from a dc source of 50 V, it is observed to operate at a speed of 2100 rpm and to draw 1.25 A. Find (a) the motor constant, (b) the no-load rotational losses of the motor, (c) the power output in horsepower of the motor when it is operating at 1700 rpm from a 48 V source, ~~and (d) the stall current and torque from a 48 V source.~~



$V = 50V$, $N_{NL} = 2100 rpm$, $I_{NL} = 1.25 A$

$E_{NL} = V - I_a R_a$

$= 48.7 V$

$\omega_{NL} = 2100 \times \frac{2\pi}{60} = 219.9 \ rad/s$

$\Rightarrow$ (a) $k\Phi = \frac{E_{NL}}{\omega_{NL}} = 0.222 \ \frac{V}{rad\,s^{-1}}$ 1

(b) $P_{NL,ROT} = E I_a = 60.9W$ 1

(c) $V = 48V$, $N_{FL} = 1700 \ rpm$

$\omega_{FL} = 178 \ rad\,s^{-1}$

$E = k\Phi \cdot \omega_{FL} = 39.52V$

$I = \frac{V - E}{R_a} = 8.233 A$

$EI_a = 325.4 W$

$P_{OP} = E I_a - P_{NL\,ROT}$

$= 264.5 W$

$= 0.355 \ hp.$ 2

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PROBLEM 2: A wound-field dc motor is driving a load whose torque requirement increases linearly with speed (squared-power load) and reaches 5 Nm at a speed of 1400 rpm. The armature terminal voltage is held to its rated value. At the rated flux the no-load speed is 1500 rpm and the full-load speed is 1400 rpm. If the flux is reduced to 80 % of the rated value, calculate the new steady-state speed.

$N_{FL} = 1400 \text{ rpm} \Rightarrow \omega_{FL} = 146.5 \text{ rad/s}$

$N_{NL} = 1500 \text{ rpm} \Rightarrow \omega_{NL} = 157.1 \text{ rad/s}$

$T_{FL} = 5 \text{ Nm} \qquad T_{load} = \omega \cdot \dfrac{T_{FL}}{\omega_{FL}}$

$$V = k\Phi\,\omega + \frac{T}{k\Phi} R_a$$

$$\omega = \frac{V}{k\Phi} + \frac{T}{(k\Phi)^2} \cdot R_a$$

$$= \omega_{NL} - (\omega_{FL} - \omega_{NL})$$

$$= 157.1 - 10.6 \quad \text{rad s}^{-1}$$

2

Let $\Phi' = 0.8\,\Phi$ and $\cancel{\omega'}$ $\omega \rightarrow \omega'$

$$\Rightarrow \omega' = \frac{V}{k\Phi'} + \frac{T'}{(k\Phi')^2} \cdot R_a$$

1

$$= \frac{V}{0.8\,k\Phi} + \frac{R_a}{(k\Phi)^2} \cdot T_{FL} \cdot \frac{\omega}{\omega_{FL}} \cdot \frac{1}{0.64^2}$$

$$\omega' = 196.375 - 0.113\,\omega'$$

$$\Rightarrow \omega' = 176.43 \text{ rad s}^{-1}$$

$N' = 1686 \text{ rpm}$ 1

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