EE462 - HOMEWORK #3

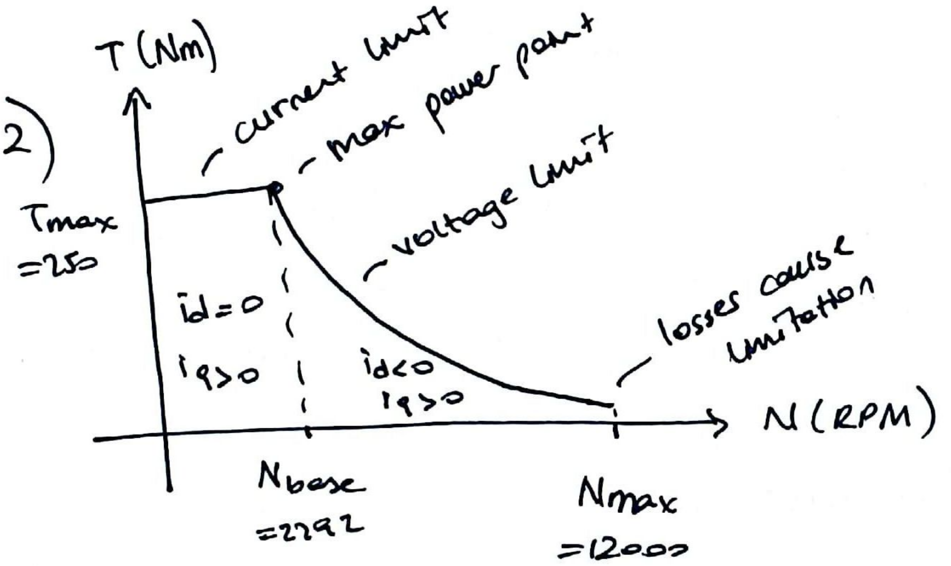
- SOLUTIONS -

PART A (40 pts)

1) $$\omega_{base} = \frac{P}{T_{max}} = \frac{60\,000}{250} = 240 \text{ rad/sec}$$

$N_{base} = 2292$ RPM (5 pts)

2)



(5 pts)

3) For SMPMSM, $T = \frac{3}{2} pp \lambda_{PM} i_q$

→ Field is created in D-axis (1pts)

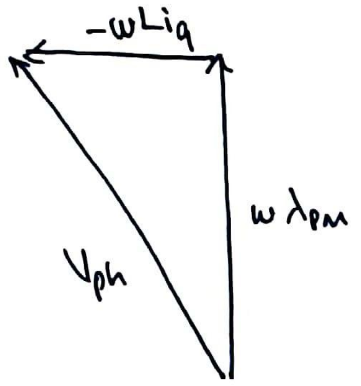
→ If $i_q = 0$, no torque will be produced. (2pts)

→ i_d is applied in field weakening region. (2pts)

4) $T = \frac{3}{2} pp \cdot \lambda_{PM} i_q \rightarrow \lambda_{PM} = \frac{250}{\frac{3}{2} \cdot 6 \cdot 250} = \frac{1}{9} = 0{,}11$ Wb.

(5 pts)

5)



→ Because of SVPWM, $V_{ph} = \frac{V_{dc}}{\sqrt{3}}$

→ Note that $\omega = \omega_e = 240 \cdot pp = 1440$ rad/sec

$$\Rightarrow \frac{V_{dc}}{\omega_e \cdot \sqrt{3}} = \sqrt{(\lambda_{pm})^2 + (L \cdot i_q)^2}$$

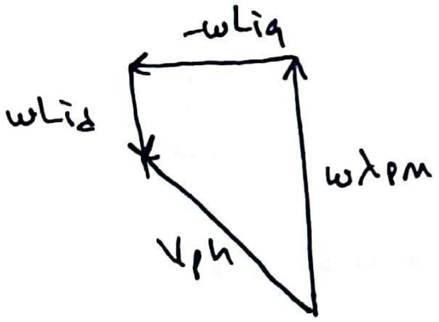
$L \cdot i_q = 0{,}1167 \quad \rightarrow \quad L_{max} = 467\ \mu H$

(6 pts)

6) $T = \frac{P_{max}}{\omega_{max}} = 47{,}75$ Nm

$T = \frac{3}{2} pp\, \lambda_{pm}\, i_q \longrightarrow i_q = 47{,}75$ A

$i_d = \sqrt{i_{max}^2 - i_q^2} = \sqrt{250^2 - 47{,}75^2} = 245{,}4$ A



$$\frac{V_{dc}}{\sqrt{3}\, \omega_e} = \sqrt{(\lambda_{pm} - L i_d)^2 + (L \cdot i_q)^2}$$

→ Solve for L, take the positive root $\Rightarrow L_{min} = 205\ \mu H$

(6 pts)

7) $205\ \mu H \leq L \leq 467\ \mu H$ (3 pts)

8) Critical parameters for magnetic design (to determine L and λ)

→ Amount and grade of magnets

→ Number of turns

→ Orientation of magnets and geo dimensions in the rotor

etc. (5 pts)

PART B (30 pts, 5 pts each)

1) → windings: copper
→ core: eddy & hysteresis
→ magnets: eddy & hysteresis
→ mechanical: friction & windage

2) Resistivity and resistance increases with temperature
$P_{cu} \propto I^2 R$ → Copper losses increase.

3) Refer to the article.

4) Eddy and hysteresis, because of continuously changing magnetic field.

5) To determine safe operation region, from thermal point of view. To determine appropriate cooling methods.

6) If the machine is idle, it still rotates but $T_e = T_{fric.}$ as $T_{load} = 0$. Therefore, I is small. All losses exist but copper losses are small compared to loaded case.

PART C (30 pts, 7.5 pts each)

1) Disadvantages of SR Machines:

→ High torque ripple

→ High acoustic noise & vibrations

→ Low power density

→ Unconventional motor drive

2) → High power density

→ High efficiency

→ High mueke usage factor

3) Resistivity of copper is lower, it provides higher efficiency.

4) → Reluctance torque

→ Rare earth free or small amount of rare earth magnets are used.