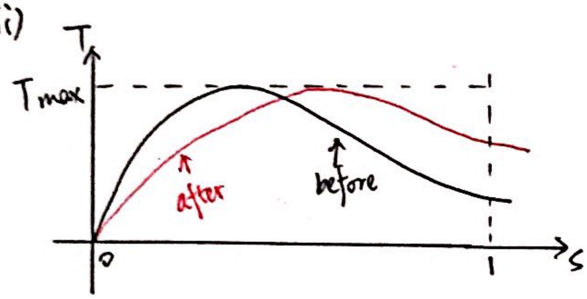
ECE 431 Midterm II. SP 2020.

Q1. a) i) increase r_2

ii)

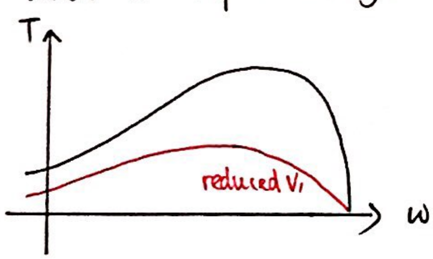


iii) yes, the efficieny will be redued (rotor loss is increased, slip is also increased)

① try to redue r_1, so that there will be less loss at stator.

② if a higher starting torque is required, a potentiometer could be used to increase rotor resistance at starting, and set potentiometer to zero at normal opreation.

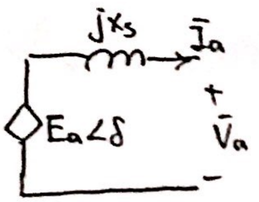
b) When the input voltage is redued, the torque curve will be affected. $(T \propto V_1^2)$



Like shown in the plot on the left.

At low speeds, when the input voltage is not large enough, the torque provided by the motor may not overcome the friction and windage loss. and thus stop. It will then lead to short circuit and have very high current, which may damange the motor.

Q2 a) 3 phase. 4 pole. 60 Hz. $|\bar{I}_a| = 20A$. $PF = 0.9$ Lagging.



generator convention., $\bar{V}_a$ as reference : $V_a = \frac{480}{\sqrt{3}} \angle 0° V$.

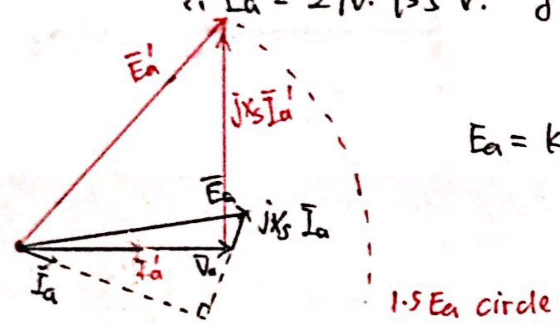
$PF = 0.9$ lagging : $\bar{I}_a = 20 \angle -\cos^{-1}(0.9) = 20 \angle -25.842° A$

$\bar{E}_a = \bar{V}_a + jX_s \bar{I}_a$

$= 277.13 \angle 0° + j(2)(20 \angle -25.842°) = 296.755 \angle 6.968° V.$

$\therefore E_a = 296.755 V. \quad \delta = 6.968°$

b)



$E_a = k_f \omega I_f$. , $I_f' = \frac{3}{2} I_f = \frac{15}{2} A \Rightarrow E_a' = 1.5 E_a$

c) $\bar{E}_a' = \bar{V}_a + jX_s \bar{I}_a'$, $E_a' = 1.5 E_a = 445.14 V.$

$445.14 \angle \delta' = 277.13 \angle 0° + j(2)(I_a' \angle 0°)$

$\hookrightarrow$ $\left.\begin{array}{l} \cos(\delta') = \frac{277.13}{445.14} \\ 445.14 \sin(\delta') = 2 I_a' \end{array}\right\}$ $\quad \delta' = 51.496°$

$I_a' = 174.176 A.$

ECE431 Midterm II. SP2020

Q3 a) key point.

1) goal: study the stability of the system.

2) method: derive from Newton's second law, neglect damping torque; assume rotor speed is close to ω_s during transient

3) result: get a relation between δ and ΔP to understand the system stability under different changes

$$\left(\frac{\partial \delta}{\partial t}\right)^2 \propto \int (P_m - P_e)\, d\delta$$

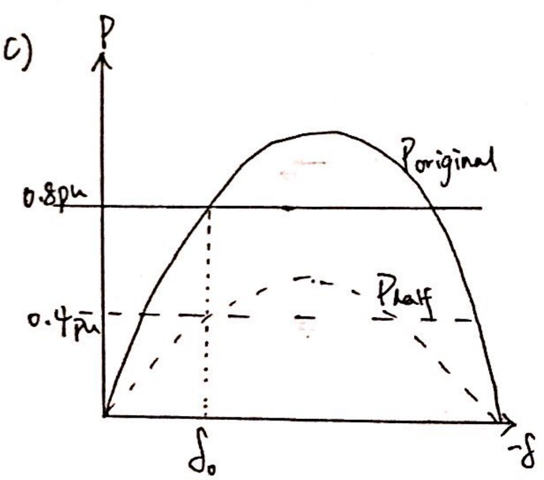
4) intepretation: only when the two areas (one for $(P_m - P_e)$; one for $(P_e - P_m)$) are equal, the system can maintain stable.

5) application: e.g. sudden load limit, critical clearing angle

b) Because the internal voltage is low ($E_a = K\omega I_f$, low field current), $P_{e\,max} = \frac{3 E_a V_a}{X_s}$ is low, and the motor operates at a higher torque angle for a given power (P_m) compared to the overexcited case. Hence, the motor can quickly approach unstable operating. (close $\delta = 90°$)

Design change: reduce X_s, E.g. increase airgap.

c)



$$\left.\begin{aligned} 0.8 &= P_{max} \sin\delta_0 \\ 0.4 &= \tfrac{1}{2} P_{max} \sin\delta_1 \end{aligned}\right\} \Rightarrow \delta_0 = \delta_1$$

no change in torque angle

no area exists

the motor is in stable motor mode.

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