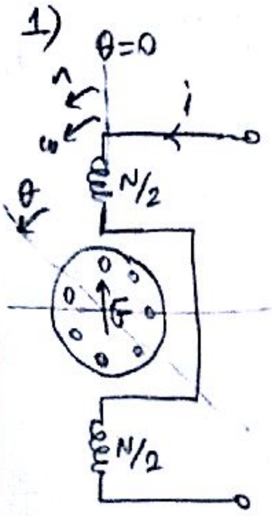
EE362-HW5 Solution

06.06.2016

1)



$i = I_m \sin(\omega t)$

a) $\mathcal{F}_0 = N i = N I_m \sin(\omega t) = \mathcal{F}_m \sin(\omega t)$ (along $\theta = 0$ axis)

$\mathcal{F}_\theta = \mathcal{F}_0 \cos(\theta) = \mathcal{F}_m \sin(\omega t)\cos(\theta)$ (along θ axis)

$$\mathcal{F}_\theta = \frac{\mathcal{F}_m}{2}\left(\sin(\omega t)\cos(\theta) + \cos(\omega t)\sin(\theta)\right) + \frac{\mathcal{F}_m}{2}\left(\sin(\omega t)\cos(\theta) - \cos(\omega t)\sin(\theta)\right)$$

$$\mathcal{F}_\theta = \underbrace{\frac{\mathcal{F}_m}{2}\cos(\omega t - \theta)}_{\text{forward travelling}} + \underbrace{\frac{\mathcal{F}_m}{2}\cos(\omega t + \theta)}_{\text{backward travelling}}$$

b)

$n_s = 120 f/p = 3000$ rpm.

$n_r = 2940$ rpm

$s_f = \dfrac{3000 - 2940}{3000} = 0.02 \Rightarrow f_f = s_f \times 50 = 1$ Hz

$s_b = (2 - s) = 1.98 \Rightarrow f_b = s_b \times 50 \approx 99.25$ Hz

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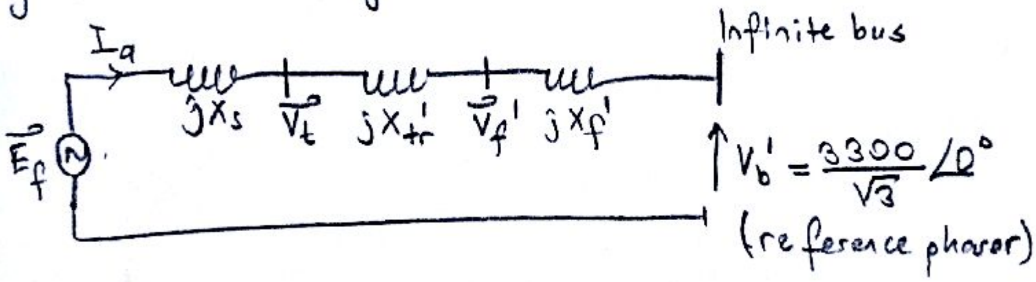
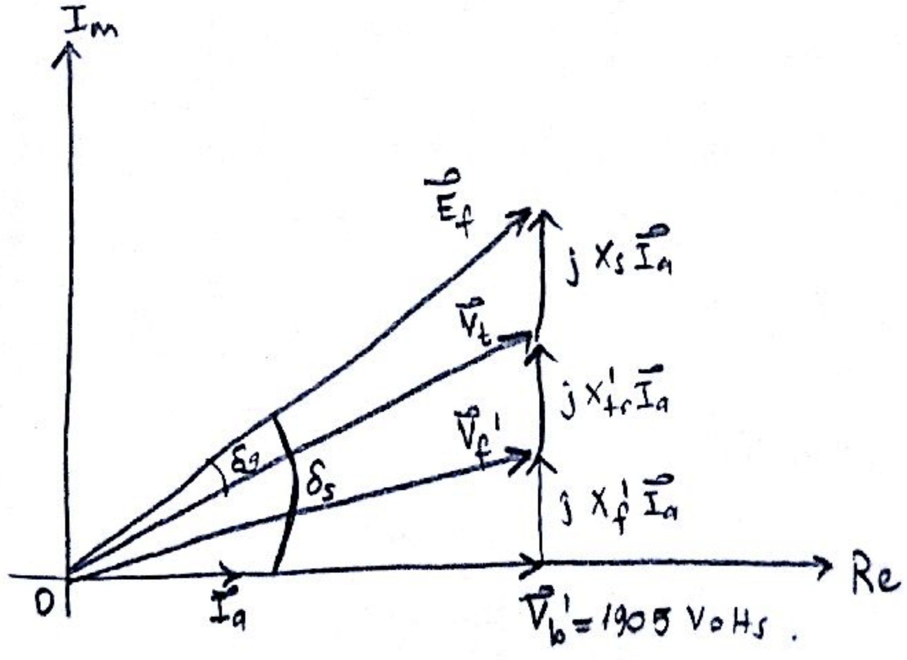
2) The equivalent circuit on per-phase-wye basis and referred to the generator side is given below:



d)



b) $S = V_b' I_a \Rightarrow I_a = \dfrac{\frac{2.4\times10^6}{3}}{\frac{3300}{\sqrt{3}}} = 420$ Amps $\Rightarrow \vec{I_a} = 420\angle 0^\circ$ (unity pf)

$\vec{V_f}' = \vec{V_b}' + jX_f' \vec{I_a} = 1905 + j42 = 1905.7 \angle 1.26^\circ$ Volts //

$\vec{V_t} = \vec{V_b}' + j(X_f' + X_{tr}')\vec{I_a} = 1905 + j168 = 1912.6 \angle 5^\circ$ Volts //

$\vec{E_f} = \vec{V_b}' + j(X_{tr}' + X_f' + X_s)\vec{I_a} = 1905 + j1932 = 2713.4 \angle 45.4^\circ$ Volts //

c) Load angle of the generator : $\delta_g = 45.4^\circ - 5^\circ = 40.4^\circ$ /

Load angle of the system : $\delta_s = 45.4^\circ$ //

d) The reactive power delivered by the generator is consumed only by the reactances since power factor at the infinite bus is unity.

Reactive power generated by the generator : $Q_f = 3 I_a^2 X_{total} = 2.2$ MVAr capacitive

Reactive power delivered by the generator : $Q_g = 3 I_a^2 (X_f' + X_{tr}')$

$Q_g = 211.7$ kVAR capacitive //

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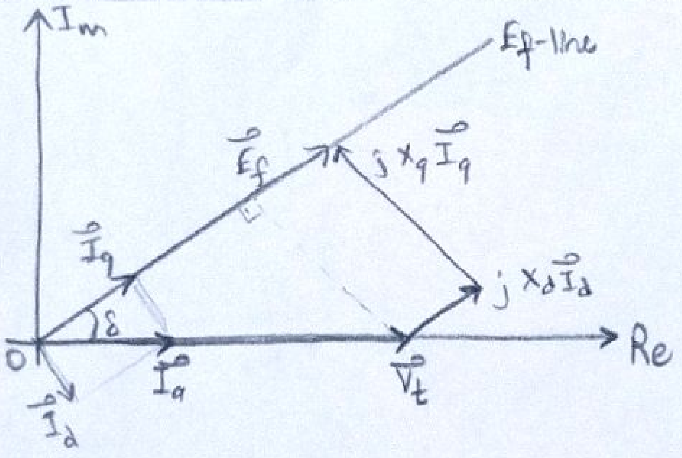
3)



a) $I_a = \dfrac{S}{\sqrt{3}V_{ll}} = \dfrac{50\times10^6}{\sqrt{3}\,10.5\times10^3} = 2.75$ kAmps.

(1) ... $I_q = I_a \cos\delta$, (3) ..... $V_t \sin\delta = X_q I_q$

(2) ... $I_d = I_a \sin\delta$, (4) ..... $E_f = V_t \cos\delta + X_d I_d$

By (1) & (3) : $V_t \sin\delta = X_q I_a \cos\delta \Rightarrow \tan\delta = \dfrac{X_q I_a}{V_t} \Rightarrow \delta = 36^\circ$ //

By (2) & (4) : $E_f = V_t \cos\delta + X_d I_a \sin\delta = 8465$ Volts/phase //

b) Losses are neglected : $P_m = P_e = 50$ MW

$$T_m = \frac{P_m}{w_s} \quad \text{where } w_s = \frac{120f}{P} \times \frac{2\pi}{60} = 62.83 \text{ rad/sec}$$

$\rightarrow T_m = 796$ kNm //

c) When the field current is zero, the only power that the generator can deliver is the reluctance power:

$$P_{reluctance} = \frac{V_t^2 (X_d - X_q)}{2 X_d X_q} \sin(2\delta) = 9.6 \text{ MW (maximum)}$$

This power is below the rated power (50 MW) of the generator.

Therefore, it cannot deliver rated power. //