330 review. (5/4)

Thursday, April 30, 2020 6:17 PM

②

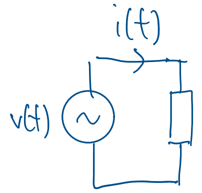
$v(t) = A\cos(\omega t + \theta)$ waveform

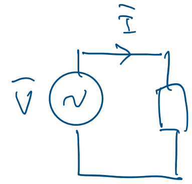
$\bar{V} = A/\sqrt{2} \angle \theta°$ phasor.

complex number.

$i(t) = B\cos(\omega t + \gamma)$

$\bar{I} = B/\sqrt{2} \angle \gamma$





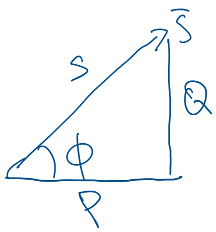
$p(t) = v(t)\, i(t)$

$\langle p \rangle = \frac{1}{T}\int_0^T p(t)\,dt$

$= \frac{1}{T}\int_0^T AB\cos(\omega t + \theta)\cos(\omega t + \gamma)\,dt$!!!

$\langle p \rangle = \mathrm{Re}\{\bar{V}\bar{I}^*\}$

$\bar{S} = \bar{V}\bar{I}^* = P + jQ = S\angle\phi$

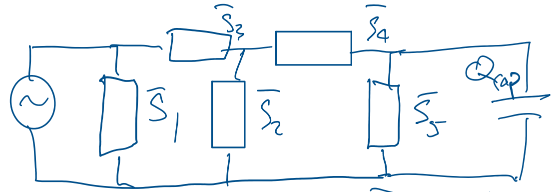


$\cos\phi$ = power factor.

$\phi > 0$ lag

$\phi < 0$ lead.

$\phi = 0$ unity (ideal)



$\bar{S}_{tot} = \bar{S}_1 + \bar{S}_2 + \bar{S}_3 + \bar{S}_4 + \bar{S}_5$

$\bar{S}_{new} = \bar{S}_{old} + Q_{cap}$

$(Q_{cap} < 0)$

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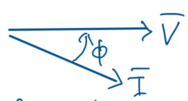
③

$\bar{Z} = R + jX$

$\bar{V} = \bar{I}\bar{Z}$

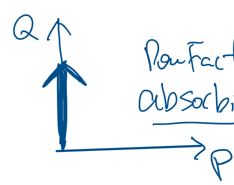
$\bar{S} = \bar{V}\bar{I}^* = |\bar{V}|^2/\bar{Z}^*$

{ Voltage – independent
{ Current – dependent.

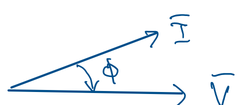


Current lags voltage. (lagging PF)

Inductor $X = \omega L > 0$

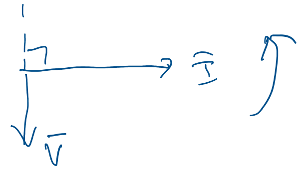


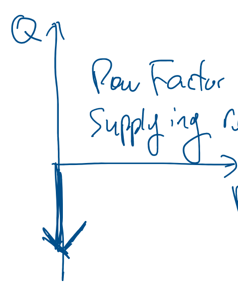
PowFact = 0.
absorbing reactive.



current leads voltage. (leading PF)

Capacitor $X = -\frac{1}{\omega C} < 0$





Pow Factor = 0
Supplying reactive power.

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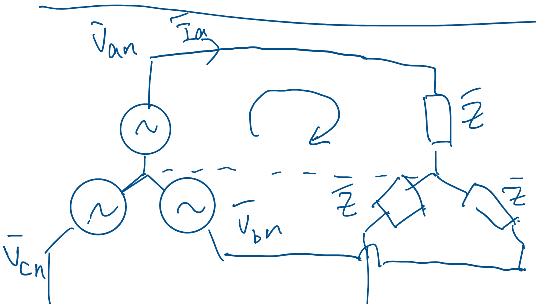
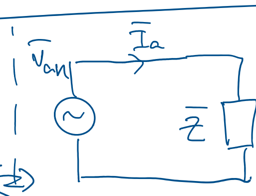
④



$\Leftrightarrow$



$|\bar{I}_a| = I_L$

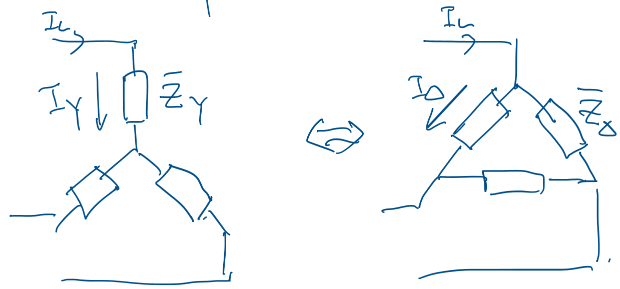
$|\bar{V}_{an}| = V_L/\sqrt{3}$

$\bar{S}_a = \frac{1}{3}\bar{S}_{abc}$

Same Power factor.

$\bar{S}_a = \frac{1}{3}\bar{S}_{abc}$

$\bar{V}_{an} = V\angle 0°$
$\bar{V}_{bn} = V\angle -120°$
$\bar{V}_{cn} = V\angle -240°$
$= V\angle +120°$
$V_L = \sqrt{3}\,|\bar{V}_{an}|$
$I_L = |\bar{I}_a|$



Power factor.

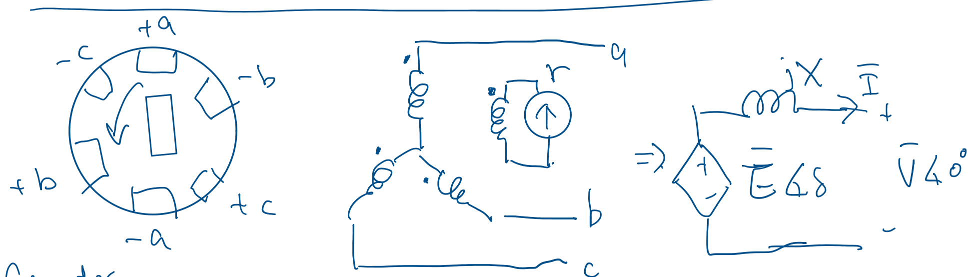
$\bar{S}_\Delta = \bar{S}_Y$

$\bar{Z}_\Delta = 3\bar{Z}_Y$

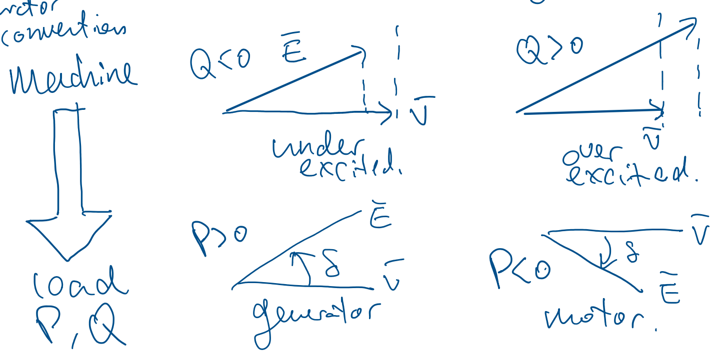
$\sqrt{3}\,I_\Delta = I_Y = I_L$
(magnitude)

Equivalence: Same complex power.
indistinguishable by the terminals.

⑤



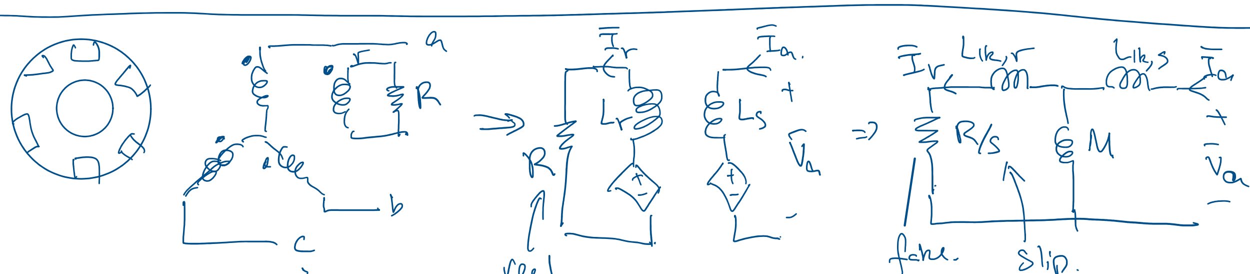
Generator convention

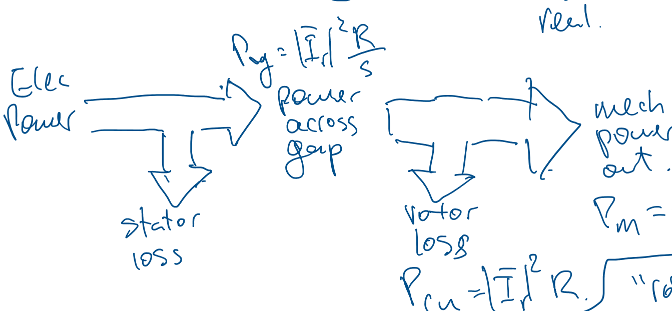


$\omega_{mech} = \left(\frac{2}{P}\right)\omega_{elec}$

$\tau\,[Nm] = \frac{\text{Power}\ [W]}{\omega_{mech}\ [rad/s]}$

⑥





60Hz → 3600 rpm.
4 poles → 1800 rpm.
real spd 1700 rpm.

$\text{Slip} = \frac{100\ rpm}{1800\ rpm}$.

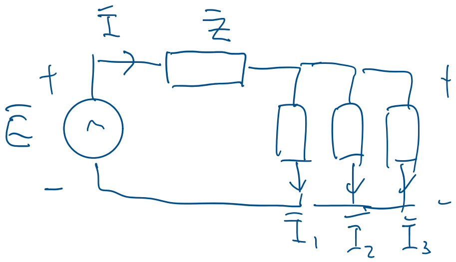
"rotor speed"
mechanical spd → $\omega_m = \left(\frac{2}{P}\right)(1-s)\,\omega_{elec}$.

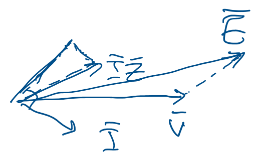
rotor freq. → $\omega_{rotor} = s\ \omega_{elec}$.

| rotor freq. → $\omega_{rotor} = s\ \omega_{elec.}$

7

$\bar{E} = \bar{V} + \bar{Z}\bar{I} = \bar{V} + R\bar{I} + jX\bar{I}$





load 1 $\quad \bar{I}_1 = \dfrac{\bar{V}}{\bar{Z}_1} = \dfrac{100}{30+j40} = \dfrac{100\angle 0^\circ}{50\angle 53.13^\circ} = 2\angle -53.13^\circ$ [A]

load 2 $\quad \bar{S}_2 = \dfrac{200}{0.8} \angle +\arccos(0.8) = 250\angle +36.87^\circ$ [VA]

$= \bar{V}\bar{I}_2^* \Rightarrow \bar{I}_2 = (\bar{S}_2/\bar{V})^* = 2.5\angle -36.87^\circ$ [A]

load 3 $\quad \bar{I}_3 = 1\angle\theta_i, \quad \phi = \theta_v - \theta_i = -\arccos(0.6) = -53.13^\circ$

leading PF

$= 1\angle +53.13^\circ$ [A] $\Rightarrow \theta_i = \theta_v - \phi$

$\bar{I} = \bar{I}_1 + \bar{I}_2 + \bar{I}_3 = 3.8 - j2.3 = 4.44\angle -31.18^\circ$ [A]

$\bar{E} = \bar{V} + \bar{I}\bar{Z} = 108.54\angle 2.8^\circ$ [V]

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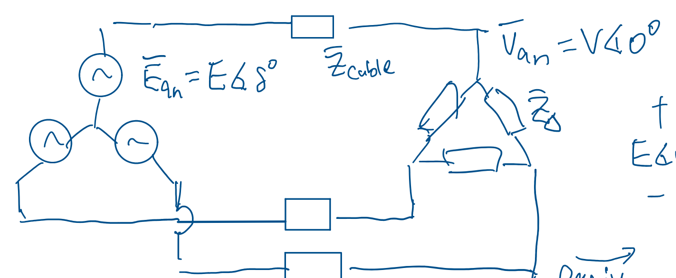
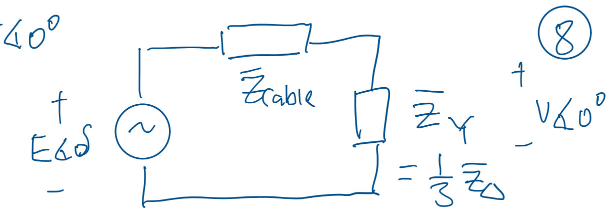
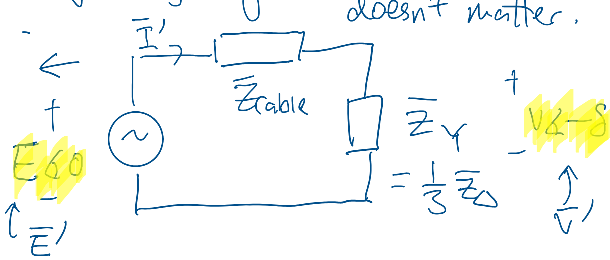


equiv →



↓ Shift by $-\delta$ b/c absolute phase doesn't matter.

$\bar{I}' = \dfrac{\bar{E}'}{\bar{Z}_{cable} + \bar{Z}_Y} = 37.3\angle -86^\circ$ [kA] ←



$\bar{V}' = \bar{Z}_Y \bar{I}' = 17.57\angle -41.42^\circ$

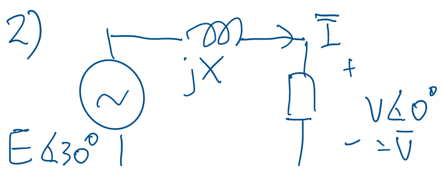
$\Rightarrow \delta = 41.42^\circ$

9

1) $P_m = \tau\,\omega_m = 5.7$ [kW] (no losses) $\Rightarrow \tau = \dfrac{5700}{60\pi} = 30.239$ [Nm]

$\omega_m = \dfrac{2}{P}\omega_s = \dfrac{1}{2}\, 120\pi = 60\pi$ [rad/s]

2)

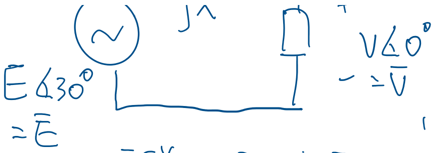


$\bar{E} = \bar{V} + jX\bar{I}$

$\boxed{\bar{I} = I_d + jI_q}$

$\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \dfrac{1}{ad-bc}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$

$\begin{bmatrix} E \\ X \end{bmatrix} = \dfrac{-1}{\ldots} \begin{bmatrix} -I_d & -\sin\delta \\ I & \cos\delta \end{bmatrix} \begin{bmatrix} V \\ 0 \end{bmatrix}$



$\frac{1}{3}\bar S_{abc} = \bar V \bar I^* = VI_d - jVI_q$

$Re\{\bar V \bar I^*\} = \frac{1}{3} P_{abc}$

$\Rightarrow I_d = \frac{1}{3}\frac{P_{abc}}{V}$

$I_q = \pm\sqrt{|\bar I|^2 - I_d^2}$

$Im\{\bar V \bar I^*\} = \frac{1}{3} Q_{abc} > 0$

$\Rightarrow I_q < 0$

$\boxed{\bar I = I_d + jI_q}$

$\Rightarrow E\cos\delta = V - XI_q$

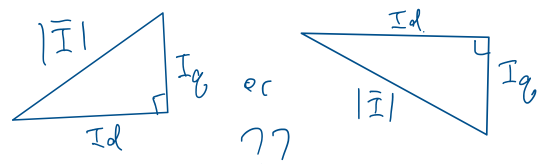
$E\sin\delta = 0 + XI_d$

$$\Rightarrow \begin{bmatrix}\cos\delta & +I_q \\ \sin\delta & -I_d\end{bmatrix}\begin{bmatrix}E \\ X\end{bmatrix} = \begin{bmatrix}V \\ 0\end{bmatrix}$$

$$\begin{bmatrix}E \\ X\end{bmatrix} = \frac{-1}{I_d\cos\delta + I_q\sin\delta}\begin{bmatrix}-I_d & -\sin\delta \\ -I_q & \cos\delta\end{bmatrix}\begin{bmatrix}V \\ 0\end{bmatrix}$$

$$\boxed{X = \frac{VI_q}{I_d\cos\delta + I_q\sin\delta}}$$

need I_d, I_q.



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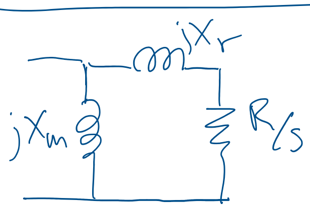

don't need this

$X_r = 2\,\Omega$, $X_m = \frac{460/\sqrt{3}}{8} = 33.198\,\Omega$

at start-up, $s = 1$,

$$|\bar I_r|^2 = \frac{V^2}{R^2 + X_r^2} = \frac{460^2/3}{0.8^2 + 2^2} = 15,201\ [A^2]$$

$$P_{ag} = 3|\bar I_r|^2 R/s = 36.482\ [kW]$$

$P_{ag} \longrightarrow P_m = (1-s)P_{ag}$; $\omega_m = (1-s)\left(\frac{2}{P}\right)\omega_s$

$\downarrow$

$P_{cu} = sP_{ag}$

$$\tau = \frac{P_m}{\omega_m} = \frac{(1-s)P_{ag}}{(1-s)\frac{2}{P}\omega_s} = \frac{P}{2}\frac{P_{ag}}{\omega_s} = 2 \cdot \frac{36.482\ [kW]}{120\pi\ [rad/s]} = 193\ Nm$$