Topics for Today:

- Announcements
  - Matlab - now we are ready to begin using it.
  - Office hrs: 2:05-2:55pm M,W,F
  - Office: EERC 614. Phone: 906.487.2857
  - Recommended problems from Ch.3, solutions posted
  - Next: Transmission Line Parameters, Chapters 4,5,6

Synchronous Machines - Chapter 3.
- Basic internal structure of machines, cylindrical vs. salient
- Field windings
- Calculation with Xd and Xq.
- Calculation Example(s)
- Concepts behind SYNCH exercise set.
- S-S behavior - Xd; Dynamic behavior - Xd'
- Short-circuit behavior - Xd"; s-s, transient, subtransient
$$V_{in} = V(I_{21})$$

$$P_{out} + C_{out}$$

$$V_{in} = V_{out} = V_{I_{21}}$$

$$I_{21} = V_{I_{21}}$$

Passive \( \Phi = V_{in} - V_{out} \)

Cons = Q_{in} = P_{in} + I_{21}

\[ \Theta = \sqrt{V_{in} - I_{21}} \]
Single-Phase

PF

LEAD

UNITY

LAG

\[ \frac{1}{\frac{1}{R} + \frac{1}{C}} \]

\[ \frac{1}{R} = \frac{v}{I} \]
\( P_{out} = \frac{E_a V_T}{X_s} \sin \delta_e \)
\( Q_{out} = \frac{E_a V_T}{X_s} \cos \delta_e - \frac{V_T^2}{X_s} \)

Typically: \( V_T \) ref 10°

\( E_a = E_{af} \ begin{array}{l} L \ end{array} \)

\( E_a, \ E_f, \ E_{af} \)

\( N \) \quad \text{they equiv of grid}

\( PF = \) ?
\[ P_{\text{out}} = \frac{E_{\text{VTR}} \sin \delta}{X_s} \]

\[ Q_{\text{out}} = \frac{E_{\text{VTR}} \cos \delta - \frac{V_f^2}{X_s}}{X_s} \]

\[ S_{\text{out}} = V I^* \]
\[ = P_{\text{out}} + j Q_{\text{out}} \]
\[ = S_{\text{into system}} \]
\[ S_m = B_r - L B_s \]

\[ P_{1 \rightarrow 2} = \frac{V_1 V_2}{X} \sin (\delta - \beta) \]
Salient vs. Non-Salient

- Salient: (rotor w/pole projections)
  - Hydro = slower speed
  - more poles
- Non-Salient: (round rotor)
  - Steam turbine, high speed
  - 2 or 4 pole

\[ P = \frac{EV \Delta T \sin \delta}{X_s} \]

electrical degrees

\[ S_e = S_m \frac{N_p}{2} \]

Torque Angle
mech.
\[ S_m = \frac{16\pi - 2\pi}{\text{mech degrees}} \]
$\frac{EaVr \sin S}{Xs}$ (rounded)
\[ P_{out} = \frac{E_a V_r}{X_d} \sin \delta + \frac{V_r^2}{2} \left( \frac{X_d - X_q}{X_d X_q} \right) \sin 2\delta \]

Cylindrical Rotor

\[ P = \frac{E_a V_r}{X_f} \sin \delta \]

\[ Q = \frac{E_a V_r}{X_s} \cos \delta \]

Eqn. (3.58)

Squirrel Rotor
KVL: \[ \vec{E}_o = \vec{I}_a (jX + R_a) + \vec{V}_T \]

\[ \Theta = \frac{\Delta \vec{V}}{\Delta \vec{I}} \]
\[ \Phi = L_{\text{in}} - L_{\text{out}} \]

Cylindrical Rotor
KVL: $E_a = V_T + I_d j X_d + I_q j X_q + \overrightarrow{I_a R_A}$

Salient Rotor
To: ee5200-l@mtu.edu
From: Bruce Mork <bamork@mtu.edu>
Subject: d-q synch machine steady-state loading calcs

First of all, notation-wise, the internal induced voltage of the synch machine is called $E_a$ in some references (voltage induced on armature windings) and in other references it’s called $E_f$ (since induced voltage on armature is due to magnitude of field current according to open-circuit characteristic of machine).

In answer to question posed:

Yes, $I_q$ by definition is exactly in phase with $E_a$. Referring to Fig. B-5 in Appendix B reference,

1) determine $I_a$ according to load specified, usually assuming $V_t = 1.0$ pu at $0^\circ$.
2,3) calculate $E_{a'}$ to find torque angle delta (this is based observation that since $jX_{dl}I_1$ is parallel to $E_a$, then $V_t + I_aR_a + jX_{ql}I_a$ lands you somewhere along the phasor $E_a$ and this allows you to determine delta.
4) knowing delta, resolve $I_a$ into its 2 components $I_a = I_d + I_q$
5) then finally, $E_a = V_t + I_aR_a + jX_{dl}I_d + jX_{ql}I_q$

As a double-check, $E_a$ must end up with the same angle (delta) that you calculated for $E_{a'}$. So, the very good thing about this is that there is a double-check built into the calculations, you can immediately see if your answer seems to be correct, i.e. if $E_{a'}$ and $E_a$ have different angles, then you messed up somewhere along the line...

Dr. Mork