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
Single-Phase

PF

LEAD

UNITY

LAG

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

\[ \frac{1}{\frac{R}{L}} \]
The circuit diagram shows a power grid with sources $E_a$, $F_f$, and $E_{af}$. The power factor $PF$ is to be determined.

- The equivalent network $N'$ is given.
- Typically, $V_T$ is referenced to $10^0$.
- $E_a = E_a L_8$
- $P_{out} = \frac{E_a V_T \sin \delta_e}{X_3} \cdot \delta_e = \frac{1}{2} \frac{E_a}{X_3} - \frac{V_T^2}{X_3}$
- $Q_{out} = \frac{E_a V_T \cos \delta_e}{X_3} - \frac{V_T^2}{X_3}$
\[ S_{\text{out}} = \bar{V}I^* \]
\[ = P_{\text{out}} + jQ_{\text{out}} \]
\[ = \bar{S}_{\text{into \ system}} \]

\[ S_m = B_r - \bar{B}_s \]

\[
P = \frac{EVT \sin \delta}{X_s} \]

\[
Q = \frac{EVT \cos \delta - \frac{V^2}{X_s}}{X_s} \]

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

(rotor w/ pole projections)
- Hydro - slower speed.
- more poles.

(round rotor)
- steam turbine, high speed.
- 2 or 4 pole.

\[ P = \frac{EVTS_0 \sin \delta}{X_s} \]
electrical Griffiths!

Torque Angle mech:
\[ S_m = \frac{B_r - B_s}{\text{mech deg.}} \]

\[ \phi = S_m \frac{Np}{2} \]
\[ E_s = E_a(jX_s + R_a) + V_t \]

\[ \theta = \frac{V}{V_s} \]

\[ \Phi = \frac{V}{V_s} \]

Cylindrical Rotor
\[ E_p = V_t + 2jx_e - 2jx + i_{RA} \]

- SALIENT ROTOR

Diagram showing voltage and current relationships.
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 \( V_t = 1.0 \text{ pu at 0}^\circ \).
2,3) calculate \( E_a' \) to find torque angle \( \delta \) (this is based observation that since \( jX_d I_d \) is parallel to \( E_a \), then \( V_t + I_a R_a + jX_q I_a \) 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, \( E_a = V_t + I_a R_a + jX_d I_d + jX_q I_q \).

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