Topics for Today:

- Announcements
  - Matlab - how was first assignment? Take feedback.
  - Office hrs: 4:05-5:55pm W,F
  - Office: EERC 614. Phone: 906.487.2857
  - Recommended problems from Ch.3, solutions posted
  - Homework SYNCH Part 1 - Due 9am Mon Oct 9th
  - 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
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°.
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
1) [20 pts] A 50-MVA delta-wye transformer is rated 115-13.8-kV. It has standard phase shift of 30° (115-kV side leads 13.8-kV side by 30°). Its self-cooled short-circuit impedance is 0.005 + j0.045 p.u. on the base of the transformer.

   a) Convert the impedance to 100 MVA base for system calculations.
   b) Determine its per unit 2x2 admittance matrix values for i) pos and ii) neg sequence, being sure to include the effect of phase shift.
   c) Repeat b) for the situation where the transformer is to connect system buses having base voltages of 115 kV and 12.47-kV. Include phase shift and off-nominal turns ratio.
Next: Synchronous Machines - Chapter 3 - Week 5

- Recommended problems & solns for Ch.3 are posted.
- Phasor diagrams - unity, lag, lead
- Salient rotor machines - calculation with Xd and Xq.
- Calculation Example(s)
- P & Q flows thru transmission lines
- More on admittance matrix [Y] construction
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\[ P_{out} = \frac{E_a V_T \sin \delta_e}{X_s} \]

\[ Q_{out} = \frac{E_a V_T \cos \delta_e - \frac{V_T^2}{X_s}}{X_s} \]

\[ E_a, E_f, E_{af} \]

Typically: \( V_T \) ref 100°

\[ E_a = E_a L8 \]

Thevenin Equivalent of Grid

[Diagram of an electrical circuit with labeled components and equations]
Salient vs. Non-Salient

(rotor w/ pole projections)
- Hydra = slower speed.
- more poles.
- steam turbine, high speed.
- 2 or 4 pole.

\[ P = \frac{ETV \sin \delta}{Xs} \]

electrical gths!

\[ Se = \frac{S_m Np}{2} \]

Torque Angle mech:
\[ S_m = (\theta - \theta_s) \]
\[ P_{\text{out}} = \frac{E_a V_T}{X_d} \sin \delta + \frac{V_T^2}{2} \left( \frac{X_d - X_q}{X_d X_q} \right) \sin 2\delta \]
KVL: \[ E_a = I_a (jX_s + R_a) + V_T \]

\[ \theta = \frac{\vec{V} - \vec{E}}{\vec{I}} \]

\[ \phi = \frac{\vec{I} - \vec{E}}{\vec{I}} \]

Diagram:
- \( E_a \)
- \( I_a \)
- \( I_{aR_a} \)
- \( jX_s \)

Cylindrical Rotor
KVL: \[ E_A = V_T + I_a R_a + I_E j X_E + I_d j X_d \]
To: ee5200-l@mtu.edu
From: Bruce Mork <bamork@mtu.edu>
Subject: d-q synch machine steady-state loading calcs

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Dr. Mork
The generator bus voltage will also be reduced as the generator operation is not maximum. This may require a change in the M.U. setting.
H₂ inside Gen

- Reduce windage losses (Pmech loss)
- Reduce H₂O vapor
- Heat transfer/cooling.