S-17.3020 Transient Phenomena in Electrical Machines
Examination 16/05/2006 at 9 – 12 o'clock, Room I 256.

1. Explain briefly:
   a) small-signal analysis,
   b) state-space equation,
   c) Runge-Kutta method,
   d) voltage behind the transient reactance and
   e) operator inductance.

2. a) List the four simplifications usually made in space-vector modelling of rotating electrical machines.

   b) Verify that the instantaneous power of a three-phase system can be expressed in terms of space vectors as $p = 3/2\,\mathrm{Re}\{\underline{u}^* \underline{i}\}$.

3. A one-phase transformer is connected to a sinusoidal voltage source $u = \hat{u}\cos\omega t$. Derive the differential equations of the primary and secondary currents. Solve the equations assuming that the load of the transformer is zero and the connection is done at time $t = 0$. The resistance and inductance of the primary winding are R_1 and L_1, and those of the secondary winding R_2 and L_2. The mutual inductance of the windings is L_m.

4. As a starting point, you have the general space-vector equations of an induction motor presented in the stator frame of reference. Derived the steady-state phasor equations of the induction motor and its one-phase, steady-state equivalent circuit.

5. After a three-phase short circuit at the terminals of a synchronous machine, the stator current in phase a and field winding current are

$$i_{sa} = -\hat{u}_{s0}\left\{\left[\frac{1}{X_d} + \left(\frac{1}{X'_d} - \frac{1}{X_d}\right)e^{-t/T'_d} + \left(\frac{1}{X''_d} - \frac{1}{X'_d}\right)e^{-t/T''_d}\right]\cos(\omega t + \vartheta_{r0})\right.$$
$$\left. -\frac{1}{2}\left(\frac{1}{X''_d} + \frac{1}{X''_q}\right)e^{-t/T_a}\cos\vartheta_{r0} - \frac{1}{2}\left(\frac{1}{X''_d} - \frac{1}{X''_q}\right)e^{-t/T_a}\cos(2\omega t + \vartheta_{r0})\right\}$$

$$i_f = i_{f0}\left[1 + \left(\frac{X_d}{X'_d} - 1\right)e^{-t/T'_d} - \left(\frac{X_d}{X'_d} - 1\right)e^{-t/T_a}\cos\omega t\right]$$

   a) To which windings are the current components and time constants associated with?
   b) What can you say about the relative magnitude of the time constants?
   c) How do the currents change if we neglect the resistances?