a State space presentation is a mathematical model of a physical system as a set of input, output and state variables related by differential equations. The variables are expressed as vectors and the differential and algebraic equations are written in matrix form

S-17.162 Advanced course in Electromechanics

Examination 28.04.2005, 12 – 15 o'clock, Lecture room I 256.

= S-17.3020

1. Explain briefly
   a) the basic machine with four windings,
   b) small-signal analysis of electrical machines,
   c) state-space presentation of a system of differential equations,
   d) what does a space-vector of a three-phase stator current mean,
   e) the four basic assumptions of space-vector theory.

1) flux density in the air gap of an electrical machine is sinusoidally distributed 2) Magnetisation curve is a straight line 3) Iron losses can be neglected 4) Resistances and inductances are independent from frequency

2. a) An electrical machine has symmetric three-phase windings both in the stator and rotor. Starting from equation

$$u = Ri + \frac{\mathrm{d}\psi}{\mathrm{d}t},$$

coordinate transformation

derive the voltage equations of the stator and rotor windings in the stator frame of reference when the flux linkages ψ are expressed as functions of the currents.

b) Separate the vector equations into real and imaginary parts, and present the system of equations in the matrix form of the two-axis theory.

3. a) Show that the instantaneous power can be calculated in terms of vector quantities as

$$P = \frac{3}{2}\,\mathrm{Re}\{\underline{u}\,\underline{i}^*\}.$$

b) Derive also the instantaneous torque expressed in terms of vector quantities.

4. a) Transform the space-vector voltage and flux equations of a cage induction motor to the equations of the small-signal theory.

b) The stator voltage of the machine running at the rated load changes slightly. Derive the equations for the resulting changes in the stator and rotor currents.

Instruction: Assume that the speed remains constant during this transient, i.e. the change in the speed can be neglected.

5. A permanent magnet synchronous motor is driving a gas turbine at its rated power ($U = U_n$, $I = I_n$, $\cos\phi = 1$, $T = T_n$, $\Omega = \omega_n/p$) when it is suddenly disconnected from the voltage supply. Derive an equation giving the stator voltage after the disconnection. The machine has no damper winding. The parameters of the stator winding are R_s, $L_d = L_q$. The torque of the turbine is proportional to the second power of the rotation speed, and the common moment of inertia of the system is J.

Instruction: After the disconnection, the permanent magnets in the rotor produce a constant flux, the amplitude of which can be calculated from the rated values. The frequency of the flux in the stator changes according to the equation of motion. All the losses of the electrical motor are assumed to be zero.