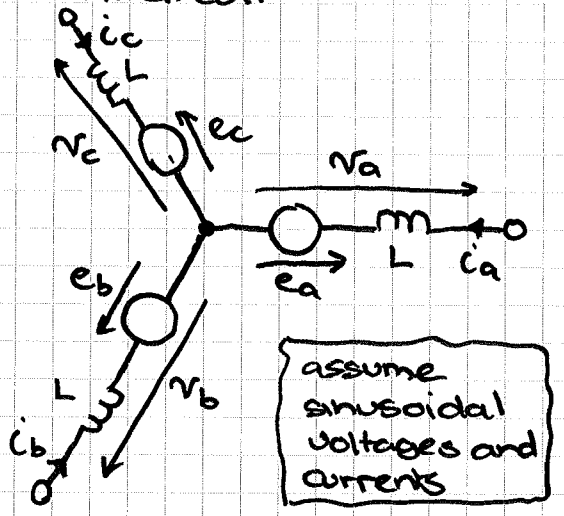
12R006 DQ TRANSFORM AND IMPLEMENTATION 30-JAN-12

Aim: give physical insight into the DQ transformation and its implementation

1. SIMPLIFIED EXPLANATION

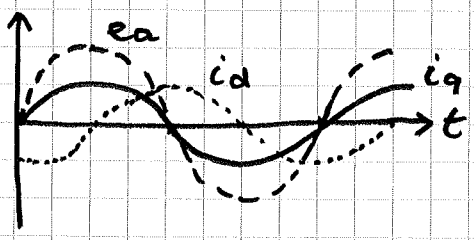
a 3-ph surface PM machine can be represented by the following equivalent circuit



voltages and currents in each phase are balanced: equal magnitudes 120° out of phase

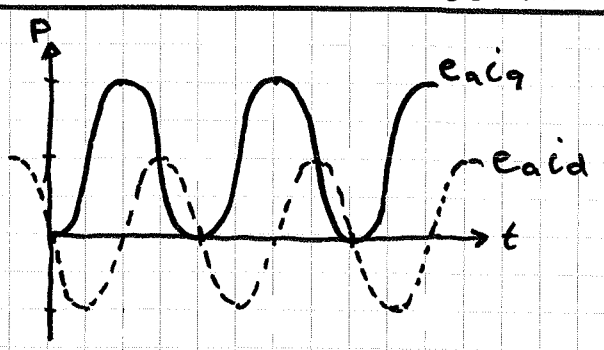
e_a : induced voltage due to PM
L : inductance of phase
V_a : terminal phase voltage
i_a : phase current

can define d-axis and q-axis currents by their phase relationship with the induced voltage e, consider phase A

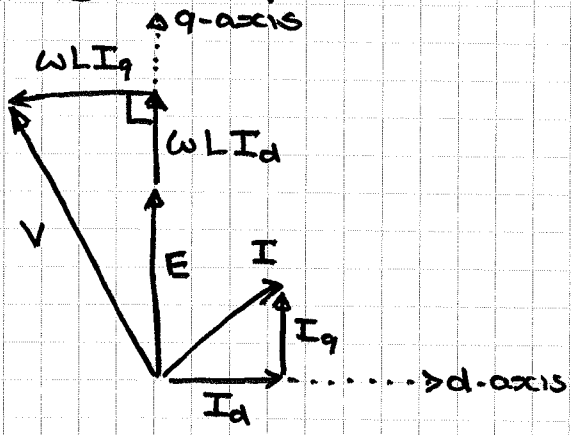


q-axis current i_q is in-phase with e
d-axis current i_d is out of phase with e

consider the instantaneous power $e_a i_q$ and $e_a i_d$



only the q-axis current produces average power in a surface PM machine



simplified phasor diagram for a surface PM machine

note that changing the d-axis current does not affect the torque but does affect the terminal voltage, usually $I_d \leq 0$.

field-weakening: at high speeds, make I_d smaller and smaller (more negative) to keep the terminal voltage to allowable limits

2. MAGNETIC FIELD EXPLANATION

the three phase coils in the machine are located 120° apart in space
magnetic fields produced by a positive current in each phase, have axes which are 120° apart

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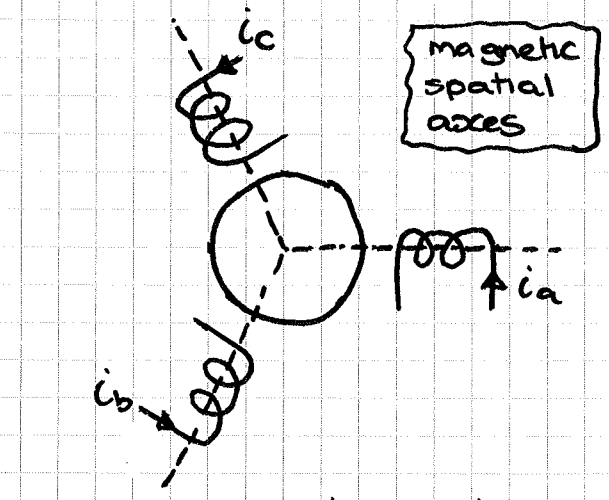
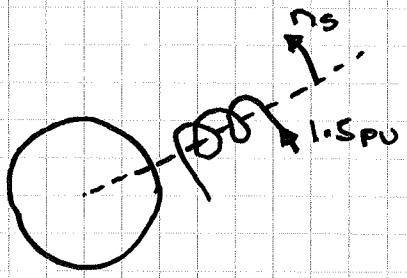
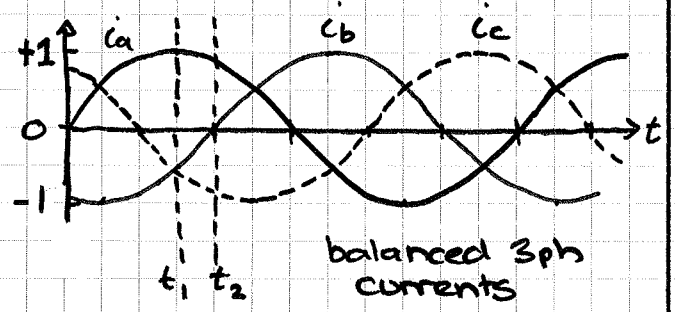


three phase balanced currents in three windings create a rotating magnetic field at synchronous speed whose magnitude is 1.5 times that produced by the peak field produced by each phase alone

rotating field equivalent to that produced by a rotating coil with a current of 1.5pu DC

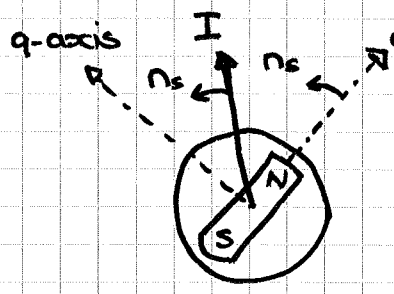




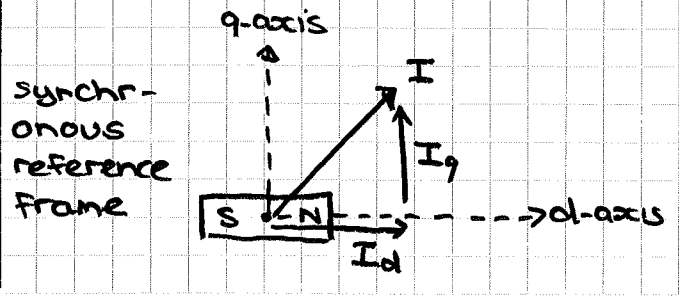
can consider as a rotating current (phasor)

the rotor of a synchronous machine is also rotating at synchronous speed

consider a PM rotor, define d-axis as direction of PM flux and q-axis as 90° leading this

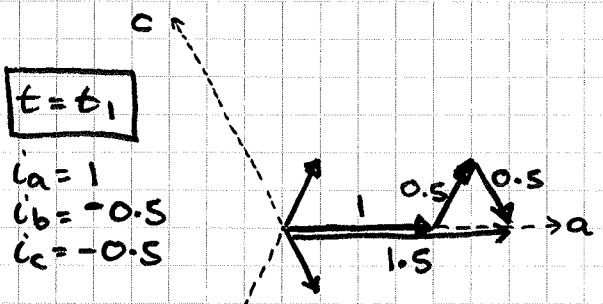


stator current phasor is not rotating relative to the rotor



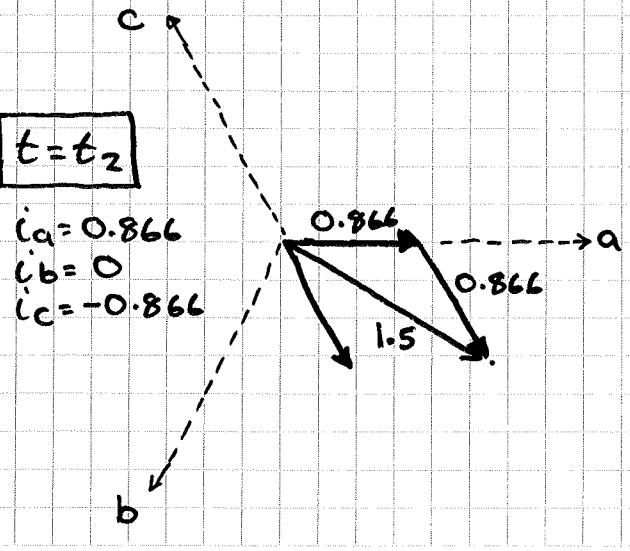
$t = t_1$

$i_a = 1$
$i_b = -0.5$
$i_c = -0.5$



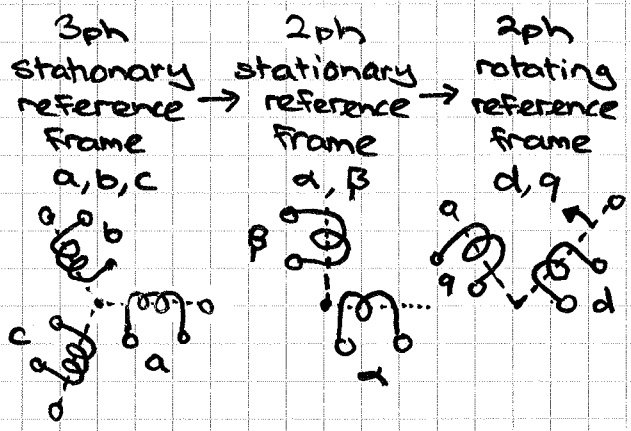
$t = t_2$

$i_a = 0.866$
$i_b = 0$
$i_c = -0.866$

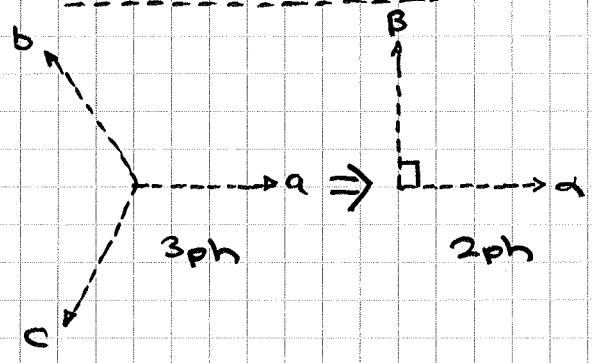


- magnet flux lies in positive d-axis, induced voltage is the rate of change of flux, thus leads magnet flux by 90°, hence in positive q-axis
- using negative values of Id reduces the flux in the d-axis and so reduces the q-axis voltage and hence terminal voltage
  (i.e. flux produced by stator current opposes magnet flux)
- torque produced by the rotor magnetic field wanting to align with the stator magnetic field.

3) TRANSFORM IMPLEMENTATION



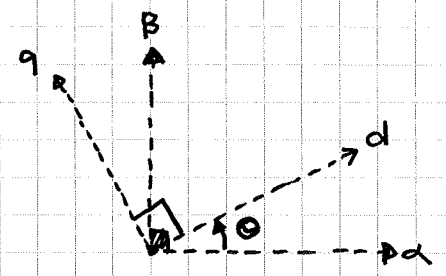
3.1. CLARKE TRANSFORM



$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

basically a projection of the 3ph quantities onto 2 stationary axes, the 2/3 factor ensures the peak value of α, β the same as the peak value of a, b, c (remember the 1.5 factor in the previous section)

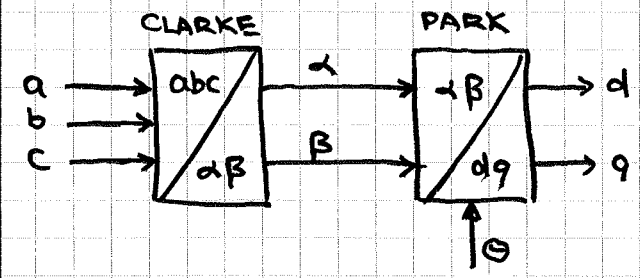
3.2. PARK TRANSFORM

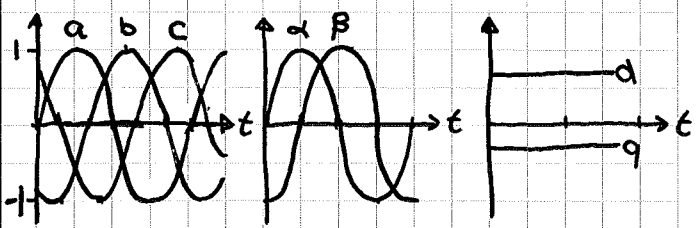


$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

rotating frame — stationary frame

3.3. BLOCK DIAGRAM





$I = 1pu$ $I = 1pu$ $I_d^2 + I_q^2 = 1$

three-phase | two-phase | two-phase

stationary frame | rotating frame (constant quantities in steady-state)

"Do not conform to the pattern of this world, but be transformed by the renewing of your mind."