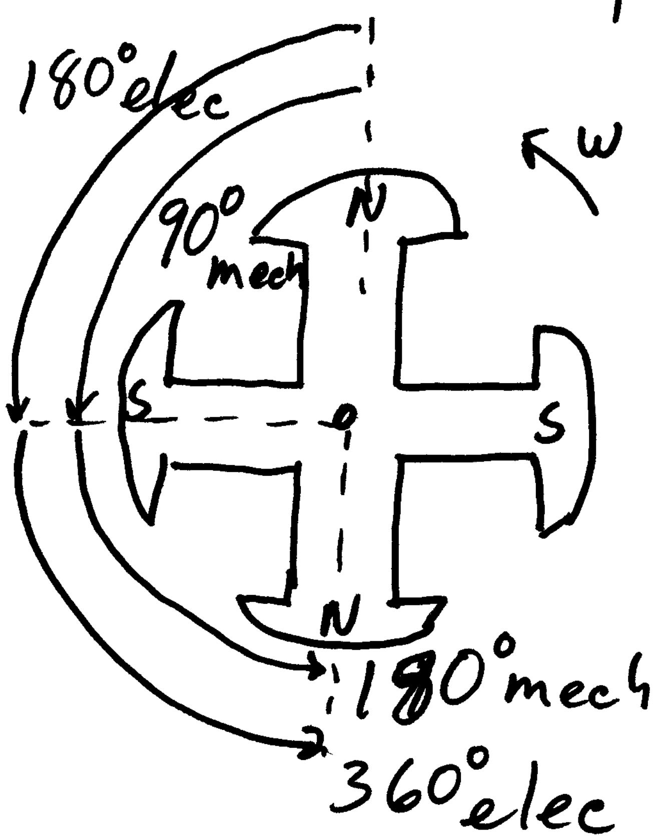
rotates at constant speed

$$n_{rpm} = \frac{120f}{\#P}$$



1 rotation of 360°

2 N poles

2 S poles

2 + peaks of V

2 − peaks of V

$$\Theta_{elec} = \frac{\#P}{2}\Theta_{mech}$$

$\frac{\#P}{2}$ = # of pole pairs

2 pole : fossil thermal plants

3600 rpm (60 Hz)

4 pole : nuclear thermal plants

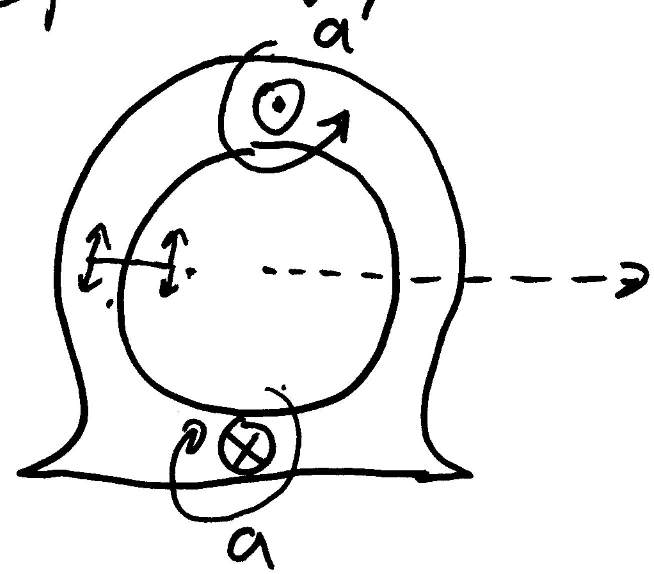
1800 rpm (60 Hz)

round rotor

less rotational losses

multipole hydro plants

Space Vector

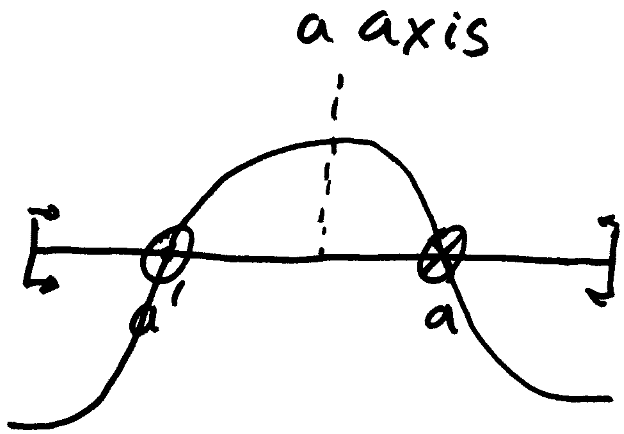


a-axis

armature

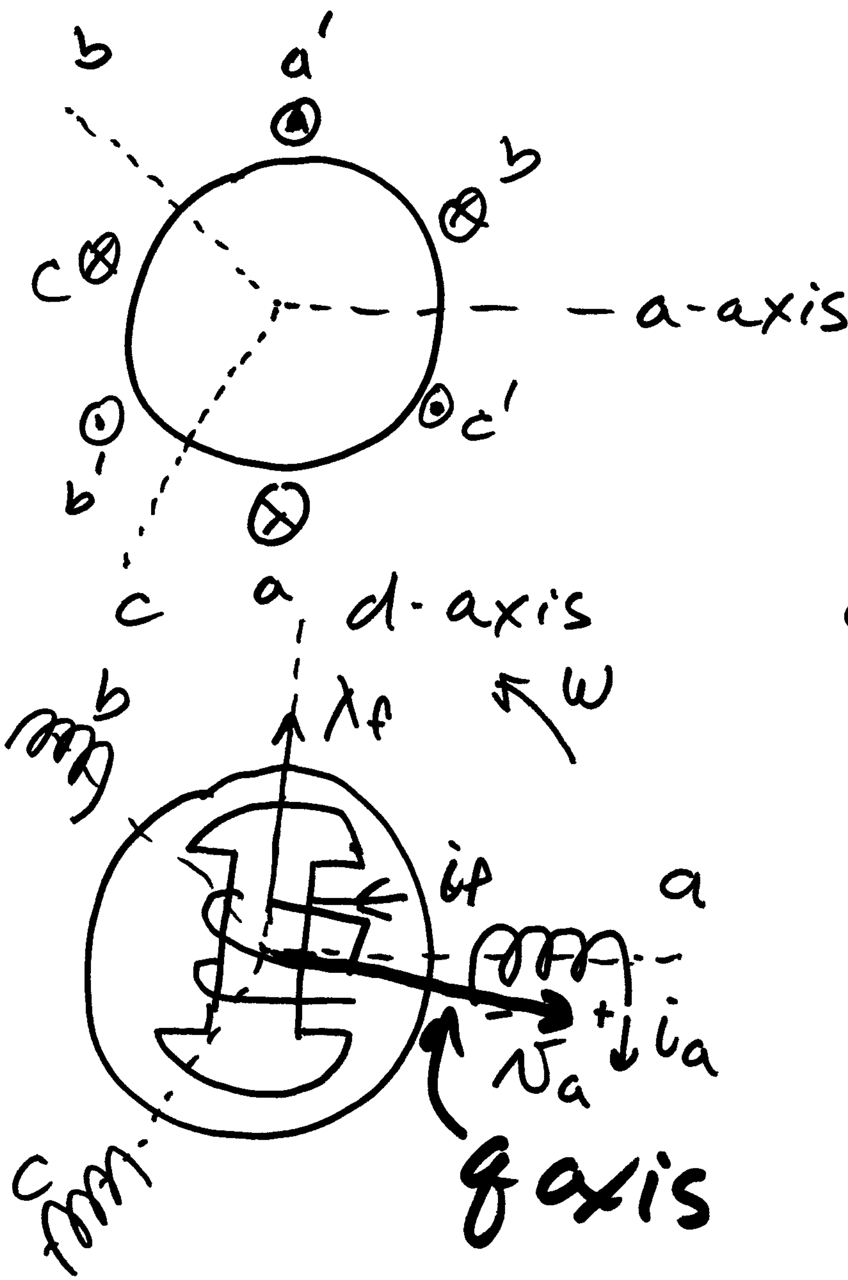
axis of the a flux

a-a' representation of a distributed winding



sinusoidal flux distribution in space

peaks @ a-axis

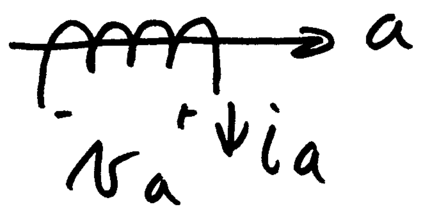


field winding
magnetic field on rotor

direct axis (d)
axis of positive field flux

quadriture axis (q)
90° behind the d axis

damper windings
one or more in d axis
one or more in q axis



$$v_a = -\frac{d}{dt}\lambda_a - R_a i_a$$

$$v_b = -\frac{d}{dt}\lambda_b - R_b i_b$$

$$v_c = -\frac{d}{dt}\lambda_c - R_c i_c$$

armature

$$\lambda_a = L_{aa} i_a + L_{ab} i_b + L_{ac} i_c + L_{af} i_f$$

$$\lambda_b = L_{ab} i_a + L_{bb} i_b + L_{bc} i_c + L_{bf} i_f$$

$$\lambda_c = L_{ac} i_a + L_{bc} i_b + L_{cc} i_c + L_{cf} i_c$$

field

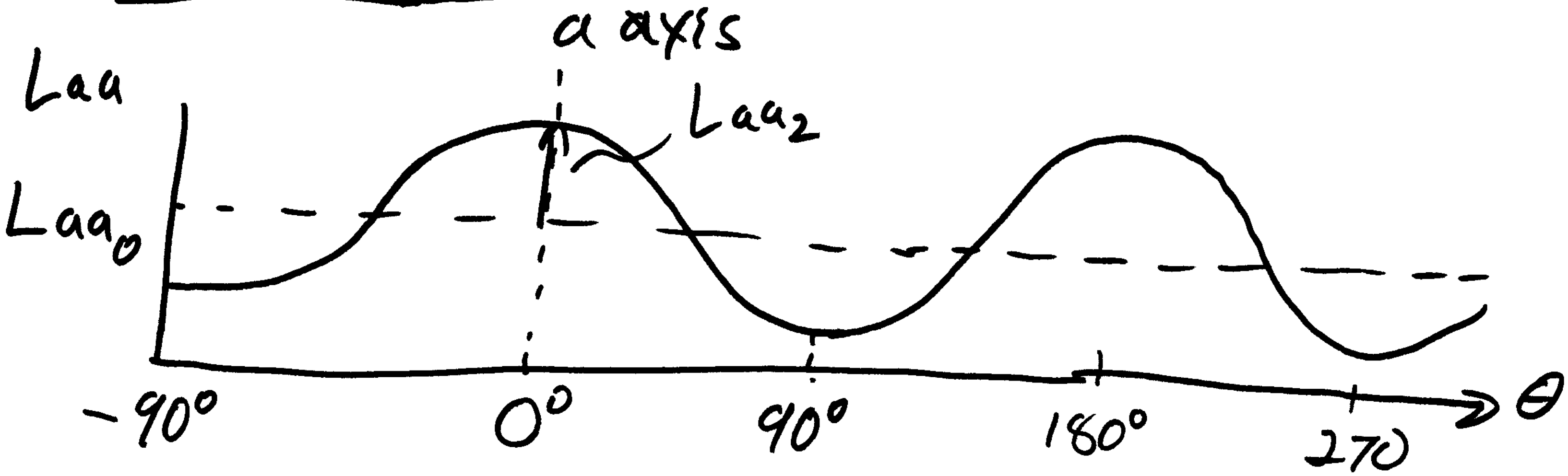
$$\lambda_f = L_{af} i_a + L_{bf} i_b + L_{cf} i_c + L_{ff} i_f$$

$$L_{xy} = N_x N_y \frac{\mu_0 \mu_r A}{l}$$

A ← cross sectional area

l ← length of magnetic circuit

$$L_{aa} = L_{aa_0} + L_{aa_2} \cos(2\theta)$$



text

$$L_{aa} = L_{aa_0} + L_{aa_2}\cos(2\theta) = L_s$$

$$L_{bb} = L_{bb_0} + L_{bb_2}\cos\left(2\theta - \frac{2\pi}{3}\right) = L_s$$

$$L_{cc} = L_{cc_0} + L_{cc_2}\cos\left(2\theta + \frac{2\pi}{3}\right) = L_s$$

$$L_{aa_0} = L_{bb_0} = L_{cc_0}$$

$$L_{aa_2} = L_{bb_2} = L_{cc_2}$$

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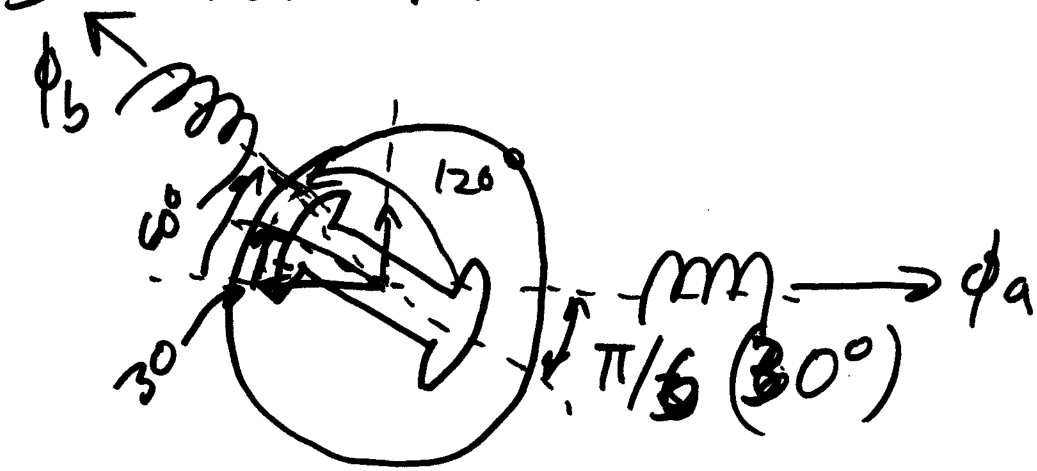
stator mutual inductances



ϕ_b subtracts from ϕ_a

	text
$L_{ab} = -L_{ab_0} - L_{ab_2} \cos\left(2\theta + \frac{\pi}{3}\right)$	$-M_s$

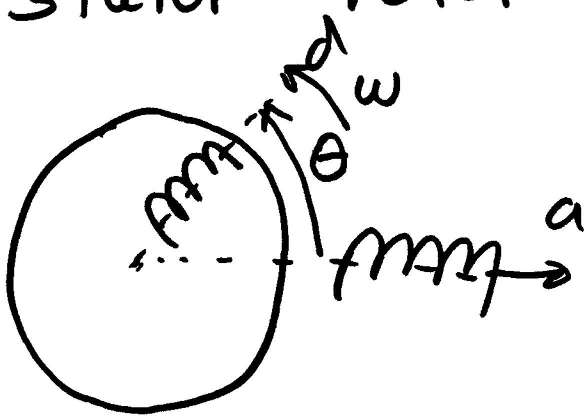
peak @ $-\frac{\pi}{6}$ or $\frac{5\pi}{6}$

$= L_{ba}$

$L_{bc} = L_{cb} = -L_{ab_0} - L_{ab_2} \cos\left(2\theta - \pi\right)$	$-M_s$
$L_{ca} = L_{ac} = -L_{ab_0} - L_{ab_2} \cos\left(2\theta - \frac{\pi}{3}\right)$	$-M_s$

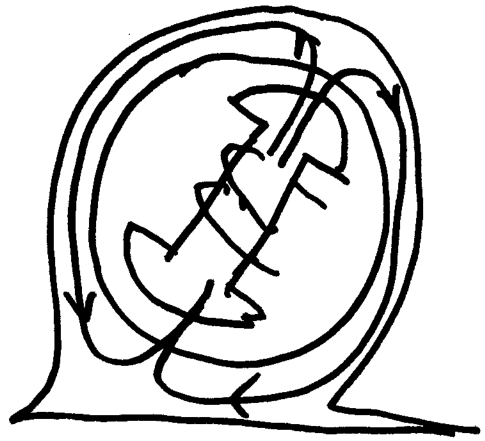
---

stator - rotor mutual inductance



	text
$L_{af} = L_{af_1} \cos\theta$	M_f
$L_{bf} = L_{af_1} \cos\left(\theta - \frac{2\pi}{3}\right)$	M_f
$L_{cf} = L_{af_1} \cos\left(\theta + \frac{2\pi}{3}\right)$	M_f

Rotor self inductance



L_{ff} = constant

field winding always sees the same magnetic circuit.

Inductances

- change value depending on rotor position
- change dramatically for salient pole machine, less so for a round rotor machine

$$\begin{bmatrix} V_a \\ V_b \\ V_c \\ V_f \end{bmatrix} = -\frac{d}{dt}\left\{ \left[\begin{array}{ccc|c} L_{aa}(\theta) & L_{ab}(\theta) & L_{ac}(\theta) & -L_{af}(\theta) \\ L_{ba}(\theta) & L_{bb}(\theta) & L_{bc}(\theta) & -L_{bf}(\theta) \\ L_{ca}(\theta) & L_{cb}(\theta) & L_{cc}(\theta) & -L_{cf}(\theta) \\ \hline -L_{af}(\theta) & -L_{bf}(\theta) & -L_{cf}(\theta) & -L_{ff}(\theta) \end{array}\right] \begin{bmatrix} i_a \\ i_b \\ i_c \\ i_f \end{bmatrix} \right\} - \begin{bmatrix} R_a & 0 & 0 & 0 \\ 0 & R_b & 0 & 0 \\ 0 & 0 & R_c & 0 \\ 0 & 0 & 0 & -R_f \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \\ i_f \end{bmatrix}$$

Upper left

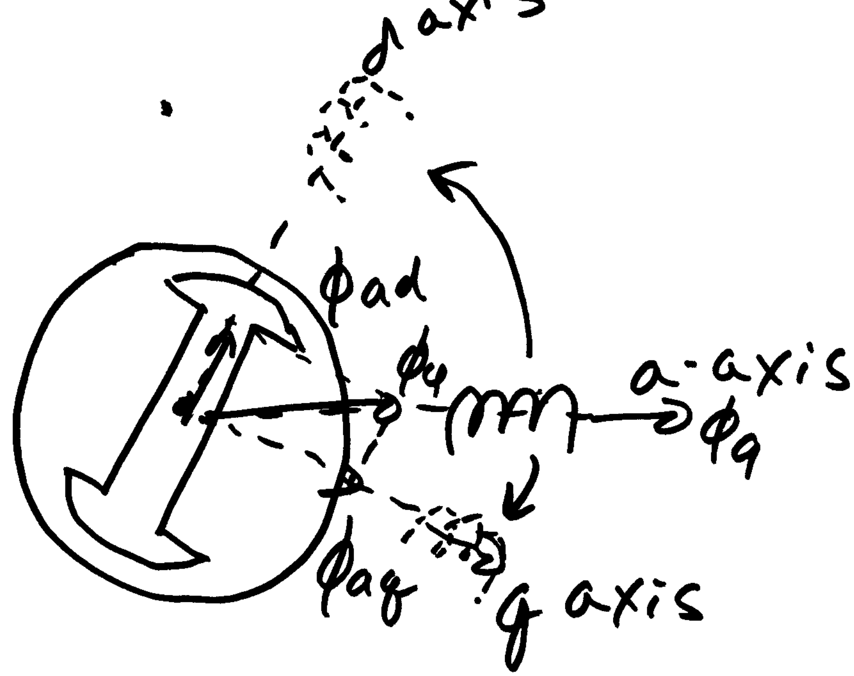
$L_{SS}(\theta)$

Upper right

$L_{SR}(\theta)$

$$v_{dq0} = T\, v_{abc}$$

$$i_{dq0} = T\, i_{abc}$$



Transformation matrix is dependent on rotor position

$$v_{abc} = -p[L_{SS}(\theta)\, i_{abc}] - p\{[L_{SR}(\theta)]\, i_f\} - R_{abc}\, i_{abc}$$

p : derivative operator