Lecture 3 - contents

A first step to motor modeling

- Determine the position dependent inductance matrix for a salient pole motor
- Obtain a qd0 model – a first look

Overview of dynamic modeling of el. machines

We are looking for??? …… (in abc reference frame)

1. Voltage equation ⇨

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = R \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix}$$

$$\begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix} = \begin{bmatrix} . & . & . \\ . & . & . \\ . & . & . \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

2. Torque equation …………….?

Reference frame transformation
Lecture 2

abc reference frame → dq reference frame **Final goal!**

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = R \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix}$$

$$\begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix} = \begin{bmatrix} . & . & . \\ . & . & . \\ . & . & . \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$\begin{bmatrix} u_q \\ u_d \\ u_0 \end{bmatrix} = R \begin{bmatrix} i_q \\ i_d \\ i_0 \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \lambda_q \\ \lambda_d \\ \lambda_0 \end{bmatrix}$$

$$\begin{bmatrix} \lambda_q \\ \lambda_d \\ \lambda_0 \end{bmatrix} \quad \begin{bmatrix} . & . & . \\ . & . & . \\ . & . & . \end{bmatrix} \begin{bmatrix} i_q \\ i_d \\ i_0 \end{bmatrix}$$

Lecture 4

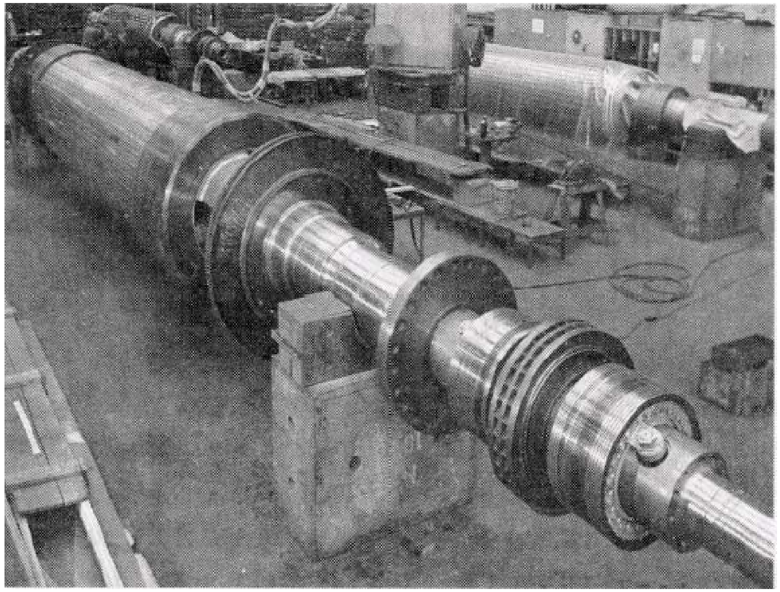
Lecture 3

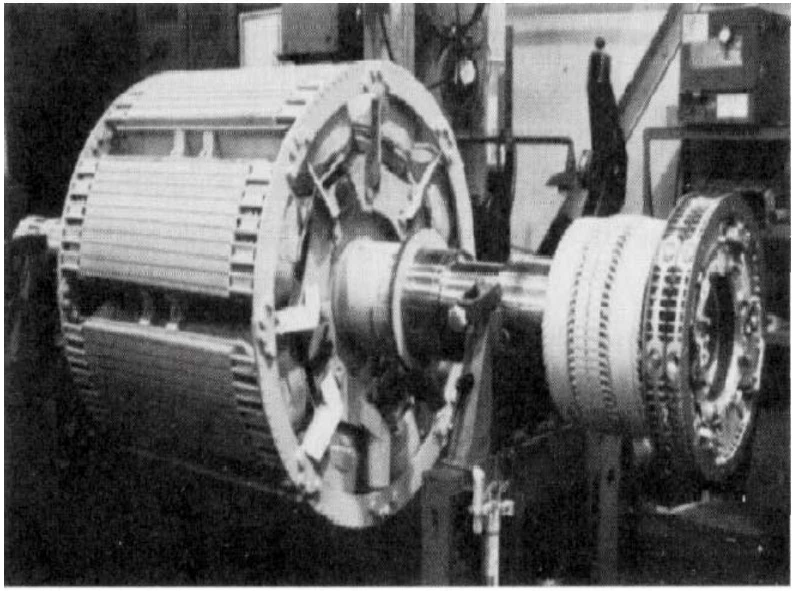
Solve the model, **lecture 1**

Complete system modelling and analysis of the salient rotor, synchronous Machine, - lecture 5

Determine the position dependent inductance matrix

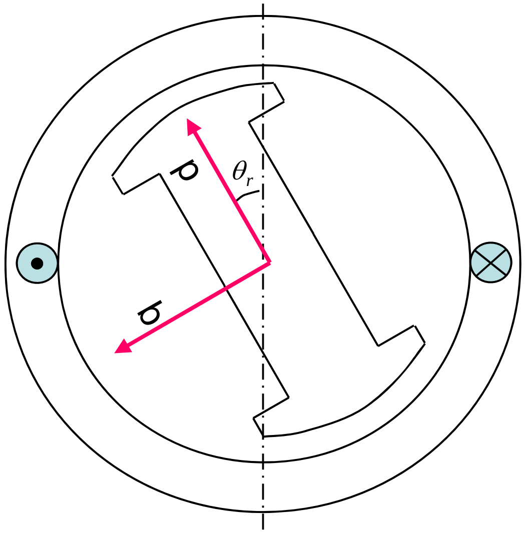
Photos of the non-salient and salient rotors





Determine the position dependent inductance matrix

Basic guidelines - continued



$$\boxed{L(\theta) = L_1 + L_2 \cos(2\theta)}$$

In qd0 system

$$L(\theta) = L_1 - L_2 \cos(2\theta_r)$$

$$\theta_r = 0 \rightarrow L(0) = L_{aaq} = L_1 - L_2$$

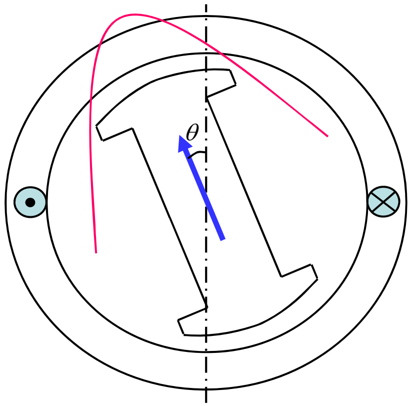
$$\theta_r = \frac{\pi}{2} \rightarrow L\left(\frac{\pi}{2}\right) = L_{aad} = L_1 + L_2$$

$$L_1 = \frac{L_{aad} + L_{aaq}}{2} \qquad L_2 = \frac{L_{aad} - L_{aaq}}{2}$$

$$L(\theta) = L_{aaq} \cos^2 \theta_r + L_{aad} \sin^2 \theta_r$$

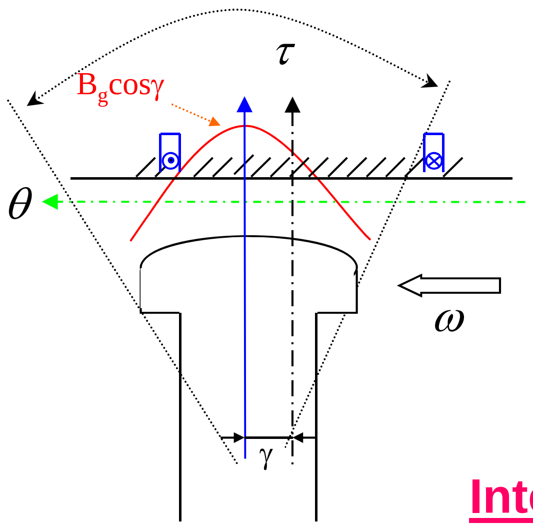
Determine the position dependent inductance matrix

Basic guidelines



$$\lambda_a = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} B_g \cos(\gamma - \theta) d\gamma \frac{1}{p} r l_{axis} = \frac{2}{\pi} B_g \tau l_{axis} \cos(\theta) = \lambda_m \cos(\theta)$$

$$\lambda_b = \int_{-\frac{\pi}{2}+\boxed{\frac{2\pi}{3}}}^{\frac{\pi}{2}+\boxed{\frac{2\pi}{3}}} B_g \cos(\gamma - \theta) d\gamma \frac{1}{p} r l_{axis} = \lambda_m \cos\left(\theta - \frac{2\pi}{3}\right)$$



$$\lambda_m \cos(\theta) \Longrightarrow \mathrm{Re}\left(\frac{e^{j\theta}}{e^{j0}}\right)$$

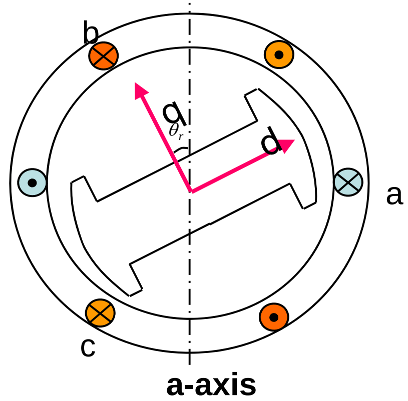
$$\lambda_m \cos\left(\theta - \frac{2\pi}{3}\right) \Longrightarrow \mathrm{Re}\left(\frac{e^{j\theta}}{e^{j\frac{2}{3}\pi}}\right)$$

Position of the flux axis

Position of the stator phase axis

Integration could be replaced by vector projection!

Determine the position dependent inductance matrix



Self-inductances of stator phases

From the book, you may see the following expressions:

$$L_{asasm} = L_1 - L_2 \cos(2\theta_r)$$

$$L_{bsbsm} = L_1 - L_2 \cos 2\left(\theta_r - \frac{2}{3}\pi\right)$$

$$L_{cscsm} = L_1 - L_2 \cos 2\left(\theta_r + \frac{2}{3}\pi\right)$$

A preferred form:

$$= L_{aaq} \cos^2 \theta_r + L_{aad} \sin^2 \theta_r$$

$$= L_{aaq} \cos^2\left(\theta_r - \frac{2\pi}{3}\right) + L_{aad} \sin^2\left(\theta_r - \frac{2\pi}{3}\right)$$

$$= L_{aaq} \cos^2\left(\theta_r + \frac{2\pi}{3}\right) + L_{aad} \sin^2\left(\theta_r + \frac{2\pi}{3}\right)$$

Determine the position dependent inductance matrix

How can we easily obtain the inductance expressions?

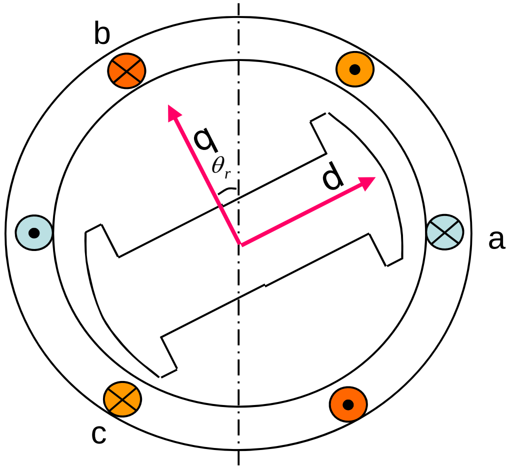
Observations:

- Each inductance expression has L_{aad} and L_{aaq} components.
- The rest coefficients are sin or cos functions of the rotor position.
- More precisely, there are **two** sin or cos coefficients before L_{aad} and L_{aaq}

Question left:
How can we determine the exact expression for sin or cos coefficients?

Determine the position dependent inductance matrix

Self-inductances of stator phases



Example:

$$L_{csc\,sm} = L_1 - L_2 \cos 2\left(\theta_r + \frac{2}{3}\pi\right)$$
$$= L_{aaq} \cos^2\left(\theta_r + \frac{2\pi}{3}\right) + L_{aad} \sin^2\left(\theta_r + \frac{2\pi}{3}\right)$$

$$L_{aaq} \cos^2\left(\theta_r + \frac{2\pi}{3}\right) \longleftrightarrow L_{aa\boxed{q}} \operatorname{Re}\left(\frac{e^{j\theta_r}}{e^{-j\frac{2\pi}{3}}}\right) \cdot \operatorname{Re}\left(\frac{e^{j\theta_r}}{e^{-j\frac{2\pi}{3}}}\right)$$

Position of the q-axis

Position of the c-axis

$$L_{aad} \sin^2\left(\theta_r + \frac{2\pi}{3}\right) \longleftrightarrow L_{aa\boxed{d}} \operatorname{Re}\left(\frac{e^{j\left(\theta_r - \frac{\pi}{2}\right)}}{e^{-j\frac{2\pi}{3}}}\right) \cdot \operatorname{Re}\left(\frac{e^{j\left(\theta_r - \frac{\pi}{2}\right)}}{e^{-j\frac{2\pi}{3}}}\right)$$

Position of the d-axis

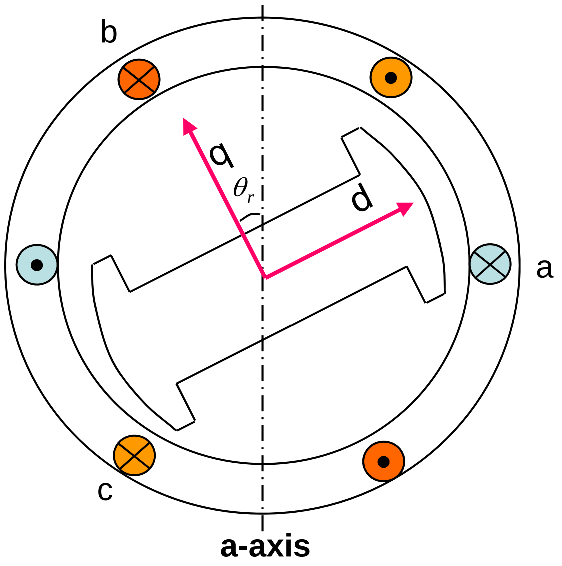
Position of the c-axis

Determine the position dependent inductance matrix

What about mutual inductance? – replace the location of the phase axis!

$$M_{asbsm} = L_{aaq}\cos\theta_r \cos\left(\theta_r - \frac{2\pi}{3}\right) + L_{aad}\sin\theta_r \sin\left(\theta_r - \frac{2\pi}{3}\right)$$

$$L_{aaq}\,\mathrm{Re}\left(\frac{e^{j\theta_r}}{e^{j0}}\right)\cdot \mathrm{Re}\left(\frac{e^{j\theta_r}}{e^{j\frac{2\pi}{3}}}\right)$$



Position of the q-axis

Position of the a-axis

Position of the b-axis

$$L_{aad}\,\mathrm{Re}\left(\frac{e^{j\left(\theta_r - \frac{\pi}{2}\right)}}{e^{j0}}\right)\cdot \mathrm{Re}\left(\frac{e^{j\left(\theta_r - \frac{\pi}{2}\right)}}{e^{j\frac{2\pi}{3}}}\right)$$

Position of the d-axis

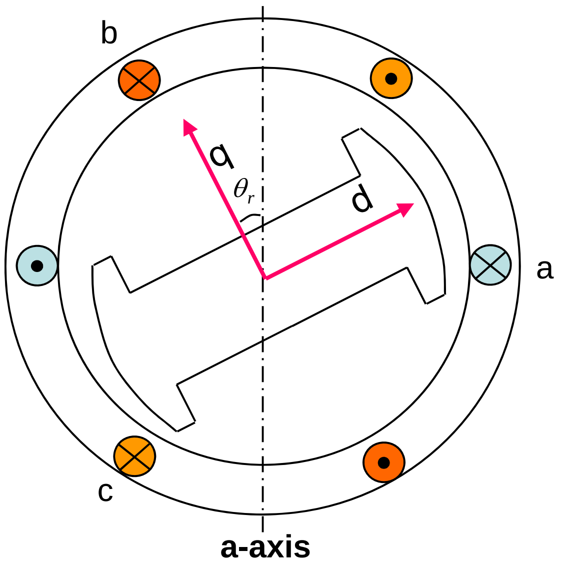
Position of the a-axis

Position of the b-axis

$$\boxed{M_{asbsm} = -\frac{1}{2}L_1 - l_2\cos\left(2\theta_r - \frac{2\pi}{3}\right)}$$

Determine the position dependent inductance matrix

Examples:



$$M_{csasm} = L_{aaq}\cos\theta_r\cos\left(\theta_r + \frac{2\pi}{3}\right) + L_{aad}\sin\theta_r\sin\left(\theta_r + \frac{2\pi}{3}\right)$$

$$L_{aaq}\,\mathrm{Re}\left(\frac{e^{j\theta_r}}{e^{j0}}\right)\cdot\mathrm{Re}\left(\frac{e^{j\theta_r}}{e^{-j\frac{2\pi}{3}}}\right)$$

Position of the q-axis

Position of the a-axis

Position of the c-axis

$$L_{aad}\,\mathrm{Re}\left(\frac{e^{j\left(\theta_r-\frac{\pi}{2}\right)}}{e^{j0}}\right)\cdot\mathrm{Re}\left(\frac{e^{j\left(\theta_r-\frac{\pi}{2}\right)}}{e^{-j\frac{2\pi}{3}}}\right)$$

Position of the d-axis

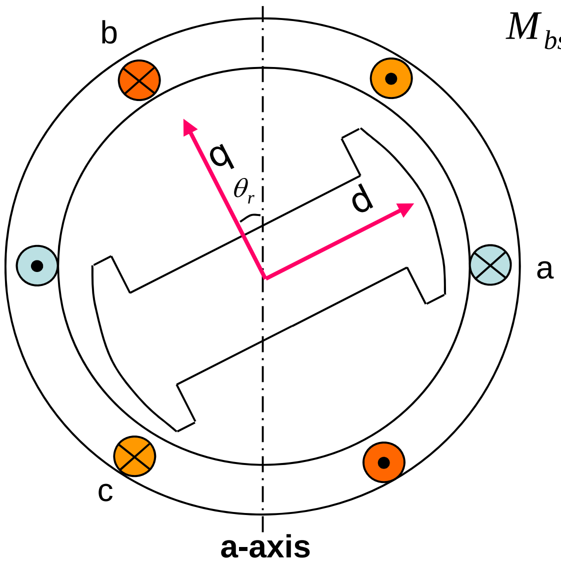
Position of the a-axis

Position of the c-axis

$$\boxed{M_{asbsm} = -\frac{1}{2}L_1 - l_2\cos\left(2\theta_r + \frac{2\pi}{3}\right)}$$

Determine the position dependent inductance matrix

Examples:



$$M_{bscsm} = L_{aaq}\cos\left(\theta_r - \frac{2\pi}{3}\right)\cos\left(\theta_r + \frac{2\pi}{3}\right) + L_{aad}\sin\left(\theta_r - \frac{2\pi}{3}\right)\sin\left(\theta_r + \frac{2\pi}{3}\right)$$

$$L_{aaq}\,\mathrm{Re}\left(\frac{e^{j\theta_r}}{e^{j\frac{2\pi}{3}}}\right)\cdot\mathrm{Re}\left(\frac{e^{j\theta_r}}{e^{-j\frac{2\pi}{3}}}\right)$$

Position of the q-axis

Position of the b-axis

Position of the c-axis

$$L_{aad}\,\mathrm{Re}\left(\frac{e^{j\left(\theta_r-\frac{\pi}{2}\right)}}{e^{j\frac{2\pi}{3}}}\right)\cdot\mathrm{Re}\left(\frac{e^{j\left(\theta_r-\frac{\pi}{2}\right)}}{e^{-j\frac{2\pi}{3}}}\right)$$

Position of the d-axis

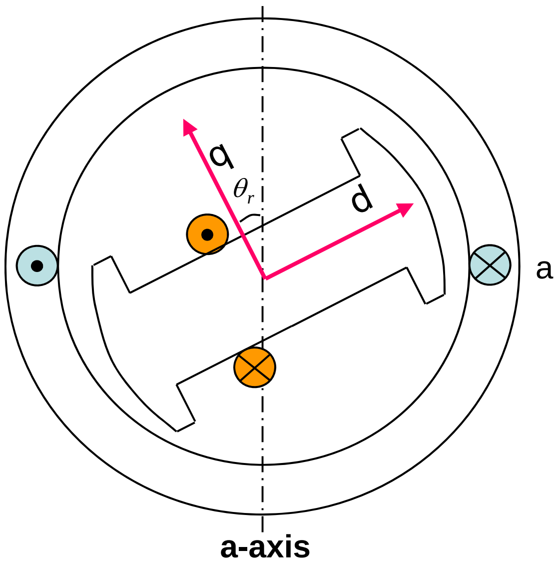
Position of the b-axis

Position of the c-axis

$$\boxed{M_{asbsm} = -\frac{1}{2}L_1 - l_2\cos(2\theta_r)}$$

Determine the position dependent inductance matrix

Mutual-inductances between rotor and stator phases



$$M_{asfdm} = L_{sfd}\cos\left(\theta_r - \frac{\pi}{2}\right) = L_{sfd}\sin\theta_r$$

$$\Uparrow$$

$$L_{sfd}\,\mathrm{Re}\left(\frac{e^{j\left(\theta_r - \frac{\pi}{2}\right)}}{e^{j0}}\right).$$

Position of the d-axis

Position of the a-axis

$$M_{bsfdm} = L_{sfd}\cos\left(\theta_r - \frac{\pi}{2} - \frac{2\pi}{3}\right) = L_{sfd}\sin\left(\theta_r - \frac{2\pi}{3}\right)$$

$$M_{csfdm} = L_{sfd}\cos\left(\theta_r - \frac{\pi}{2} + \frac{2\pi}{3}\right) = L_{sfd}\sin\left(\theta_r + \frac{2\pi}{3}\right)$$

Compare all these results with Paul C Krause's book on P53
Definition of the rotor position and qd-axis is given on P49

Obtain a qd0 model – a first look

Stator voltage equations

- Neglect all the all the rotor windings, and rotor permanent magnets (if any)
- General voltage equation $\boxed{u = Ri + \frac{d\lambda}{dt}}$

$$\underline{\lambda} = \begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix} = \begin{bmatrix} L_{aal} & -M_{ml} & -M_{ml} \\ -M_{ml} & L_{bbl} & -M_{ml} \\ -M_{ml} & -M_{ml} & L_{ccl} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_{asasm} & M_{asbsm} & M_{ascsm} \\ M_{bsasm} & L_{bsbsm} & M_{bscsm} \\ M_{csasm} & M_{csbsm} & L_{cscsm} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$\underline{L}_l$

$\underline{L}_m$

$$\underline{\lambda}_l = \underline{L}_l \cdot \underline{i}$$

$$\underline{\lambda}_m = \underline{L}_m \cdot \underline{i}$$

Leakage flux linkage

Main flux linkage

Obtain a qd0 model – a first look

Leakage mutual inductance is zero!

$$\underline{\lambda} = \begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix} = \begin{bmatrix} L_{aal} & 0 & 0 \\ 0 & L_{bbl} & 0 \\ 0 & 0 & L_{ccl} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_{asasm} & M_{asbsm} & M_{ascsm} \\ M_{bsasm} & L_{bsbsm} & M_{bscsm} \\ M_{csasm} & M_{csbsm} & L_{cscsm} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$\underline{L}_l$$

$$\underline{\lambda}_l = \underline{L}_l \cdot \underline{i}$$

Leakage flux linkage

$$\underline{L}_m$$

$$\underline{\lambda}_m = \underline{L}_m \cdot \underline{i}$$

Main flux linkage

Take care of this part first!

Obtain a qd0 model – a first look

Transformation of the main inductance matrix

$$\underline{\lambda_m} = \underline{L_m} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} L_{asasm} & M_{asbsm} & M_{ascsm} \\ M_{bsasm} & L_{bsbsm} & M_{bscsm} \\ M_{csasm} & M_{csbsm} & L_{cscsm} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$qd0 \sim \frac{2}{3} \begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin\theta & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \sim abc$$

$$\underline{\lambda_m} = L_{aaq} \begin{bmatrix} \cos\theta_r \\ \cos\left(\theta_r - \frac{2\pi}{3}\right) \\ \cos\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} \cos\theta_r & \cos\left(\theta_r - \frac{2\pi}{3}\right) & \cos\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} +$$

$$L_{aad} \begin{bmatrix} \sin\theta_r \\ \sin\left(\theta_r - \frac{2\pi}{3}\right) \\ \sin\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} \sin\theta_r & \sin\left(\theta_r - \frac{2\pi}{3}\right) & \sin\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

Obtain a qd0 model – a first look

Transformation of the main inductance matrix

$$\underline{\lambda_m} = \underline{L_m}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} L_{asasm} & M_{asbsm} & M_{ascsm} \\ M_{bsasm} & L_{bsbsm} & M_{bscsm} \\ M_{csasm} & M_{csbsm} & L_{cscsm} \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$qd0 \sim \frac{2}{3}\begin{bmatrix} \cos\theta & \cos\left(\theta-\frac{2\pi}{3}\right) & \cos\left(\theta+\frac{2\pi}{3}\right) \\ \sin\theta & \sin\left(\theta-\frac{2\pi}{3}\right) & \sin\left(\theta+\frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \sim abc$$

$$\underline{\lambda_m} = L_{aaq}\begin{bmatrix} \cos\theta_r \\ \cos\left(\theta_r-\frac{2\pi}{3}\right) \\ \cos\left(\theta_r+\frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} \cos\theta_r & \cos\left(\theta_r-\frac{2\pi}{3}\right) & \cos\left(\theta_r+\frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} +$$

$$\boxed{\frac{3}{2}i_q}$$

$$L_{aad}\begin{bmatrix} \sin\theta_r \\ \sin\left(\theta_r-\frac{2\pi}{3}\right) \\ \sin\left(\theta_r+\frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} \sin\theta_r & \sin\left(\theta_r-\frac{2\pi}{3}\right) & \sin\left(\theta_r+\frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$\boxed{\frac{3}{2}i_d}$$

Obtain a qd0 model – a first look

Transformation of the main inductance matrix - continued

$$\underline{\lambda_m} = \begin{bmatrix} \cos\theta_r \\ \cos\left(\theta_r - \frac{2\pi}{3}\right) \\ \cos\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \boxed{\left(\frac{3}{2} L_{aaq} i_q\right)} + \begin{bmatrix} \sin\theta_r \\ \sin\left(\theta_r - \frac{2\pi}{3}\right) \\ \sin\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \boxed{\left(\frac{3}{2} L_{aad} i_d\right)}$$

$$\begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & 1 \end{bmatrix} \begin{bmatrix} \lambda_q \\ \lambda_d \\ \lambda_0 \end{bmatrix}$$

$$\begin{bmatrix} \lambda_{am} \\ \lambda_{bm} \\ \lambda_{cm} \end{bmatrix} = \begin{bmatrix} \cos\theta_r \\ \cos\left(\theta_r - \frac{2\pi}{3}\right) \\ \cos\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \boxed{\lambda_{qm}} + \begin{bmatrix} \sin\theta_r \\ \sin\left(\theta_r - \frac{2\pi}{3}\right) \\ \sin\left(\theta_r + \frac{2\pi}{3}\right) \end{bmatrix} \boxed{\lambda_{dm}}$$

$$\lambda_{qm} = L_{mq} i_q \qquad L_{mq} = \frac{3}{2} L_{aaq}$$

$$\lambda_{dm} = L_{md} i_d \qquad L_{md} = \frac{3}{2} L_{aad}$$

Obtain a qd0 model – a first look

Leakage mutual inductance is zero!

$$\underline{\lambda} = \begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix} = \begin{bmatrix} L_{aal} & 0 & 0 \\ 0 & L_{bbl} & 0 \\ 0 & 0 & L_{ccl} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_{asasm} & M_{asbsm} & M_{ascsm} \\ M_{bsasm} & L_{bsbsm} & M_{bscsm} \\ M_{csasm} & M_{csbsm} & L_{cscsm} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$\underline{L_l}$

$$\underline{\lambda}_l = \underline{L}_l \cdot \underline{i}$$

Leakage flux linkage

$\underline{L_m}$

$$\underline{\lambda}_m = \underline{L}_m \cdot \underline{i}$$

Main flux linkage

Now take care of this part first!

Obtain a qd0 model – a first look

Transformation of the leakage inductance matrix

$$\underline{\lambda_l} = \underline{L_l}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} L_{aal} & 0 & 0 \\ 0 & L_{bbl} & 0 \\ 0 & 0 & L_{ccl} \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$qd0 \sim \frac{2}{3}\begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin\theta & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \sim abc$$

Multiply both sides by the transformation matrix

$$\underline{\lambda_{lq}} = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \end{bmatrix} L_{ls}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$\boxed{\begin{aligned} \lambda_{lq} &= L_{aal} i_q = L_{ls} i_q \\ \lambda_{ld} &= L_{aal} i_d = L_{ls} i_d \end{aligned}}$$

$$L_{aal} = L_{bbl} = L_{ccl} = L_{ls}$$

Obtain a qd0 model – a first look

Obtain the 0-squence equation

$$\lambda_0 = \frac{1}{3}\begin{bmatrix}1 & 1 & 1\end{bmatrix}\begin{bmatrix}\lambda_a \\ \lambda_b \\ \lambda_c\end{bmatrix} = \frac{1}{3}\begin{bmatrix}1 & 1 & 1\end{bmatrix}\begin{bmatrix}L_{aal} & 0 & 0 \\ 0 & L_{bbl} & 0 \\ 0 & 0 & L_{ccl}\end{bmatrix}\begin{bmatrix}i_a \\ i_b \\ i_c\end{bmatrix} + \boxed{0}$$

$$\lambda_0 = \frac{1}{3}\begin{bmatrix}1 & 1 & 1\end{bmatrix}\begin{bmatrix}\lambda_a \\ \lambda_b \\ \lambda_c\end{bmatrix} = \frac{1}{3}\begin{bmatrix}L_{aal} & L_{bbl} & L_{ccl}\end{bmatrix}\begin{bmatrix}i_a \\ i_b \\ i_c\end{bmatrix}$$

$$\lambda_0 = L_0 i_0 \qquad i_0 = \frac{1}{3}\left(i_a + i_b + i_c\right)$$

$$u_0 = R i_0 + \frac{d\lambda_0}{dt} \qquad L_0 = L_{aal} = L_{bbl} = L_{ccl}$$

Obtain a qd0 model – a first look

Now we should be able to answer the following questions

- Why there is a coefficient 3/2 before the q- or d-axis inductance?
- The essential part of the qd0 model is that the inductance becomes position independent – how this is achieved?
- Does the qd0 model have a decoupled q-axis and d-axis flux linkage?
- Does the qd0 model have a decoupled q-axis and d-axis voltage?

Excises

- Derive the self and mutual stator inductances, and mutual inductance between stator phase a and rotor phase b for an induction motor using the ‘projection’ method presented in the previous slides.

- If the resistance of stator phase a, b and c is R, what is the resistance in the 0-sequence equation? Please prove it.

Induction machine stator and rotor phase axes may be represented as