Title : Different reference frame s

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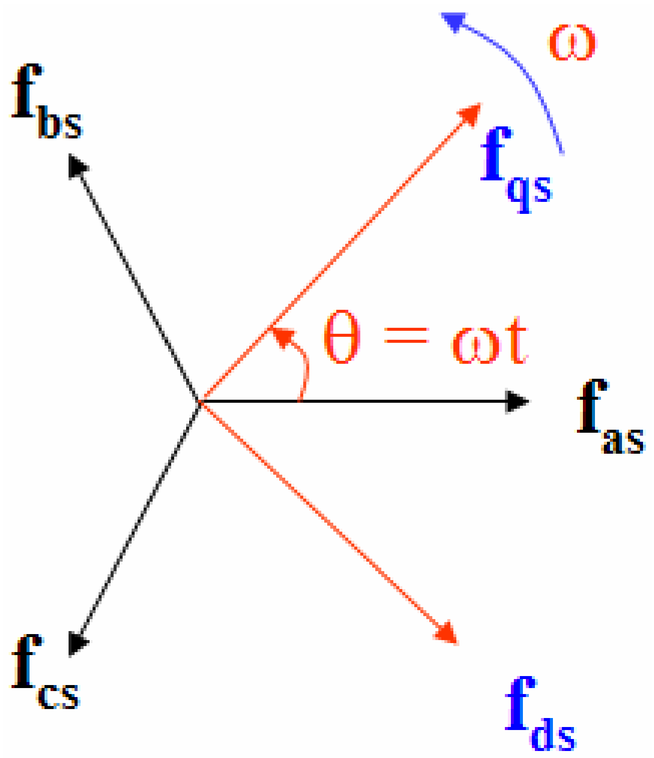
Lecture No : 01

Source of information : G K Dubey (book)

Arbitrary Reference Frame Theory



- Synchronous and induction machine inductances are functions of the rotor speed, therefore the coefficients of the differential equations (voltage equations) which describe the behaviour of these machines are time-varying.
- A change of variables can be used to reduce the complexity of machine differential equations, and represent these equations in another reference frame with constant coefficients. A change of variables which formulates a transformation of the 3-phase variables of stationary circuit elements to the
- arbitrary reference frame may be expressed as

$$\mathbf{f}_{qd0s} = \mathbf{K}_s \mathbf{f}_{abcs}$$

$$where,\quad (\mathbf{f}_{qd0s})^T = \begin{bmatrix} f_{qs} & f_{ds} & f_{0s} \end{bmatrix},$$

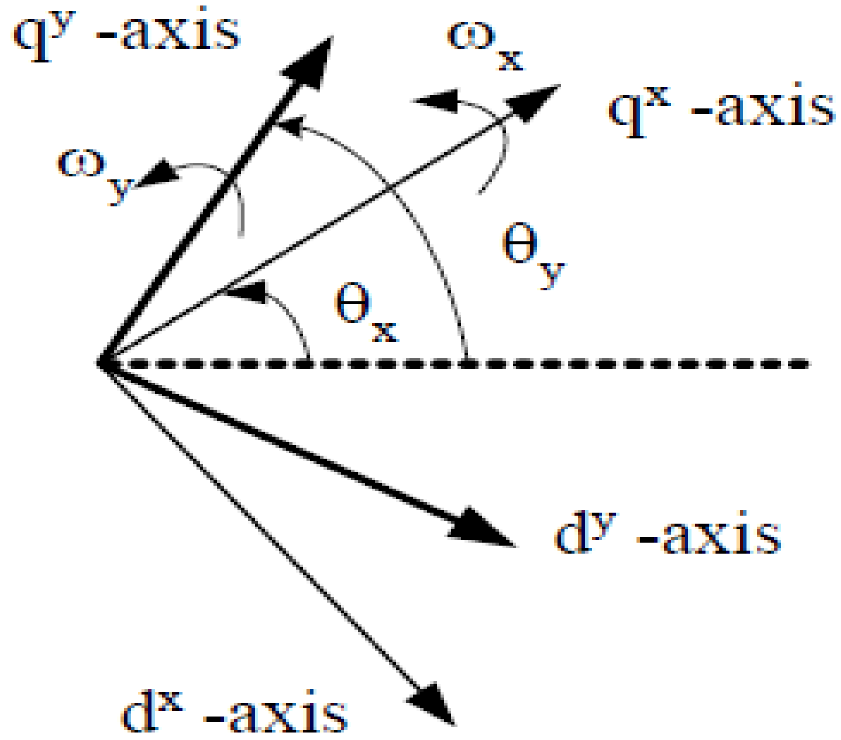
$$(\mathbf{f}_{abcs})^T = \begin{bmatrix} f_{as} & f_{bs} & f_{cs} \end{bmatrix},$$

$$\mathbf{K}_s = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ \sin\theta & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix},$$

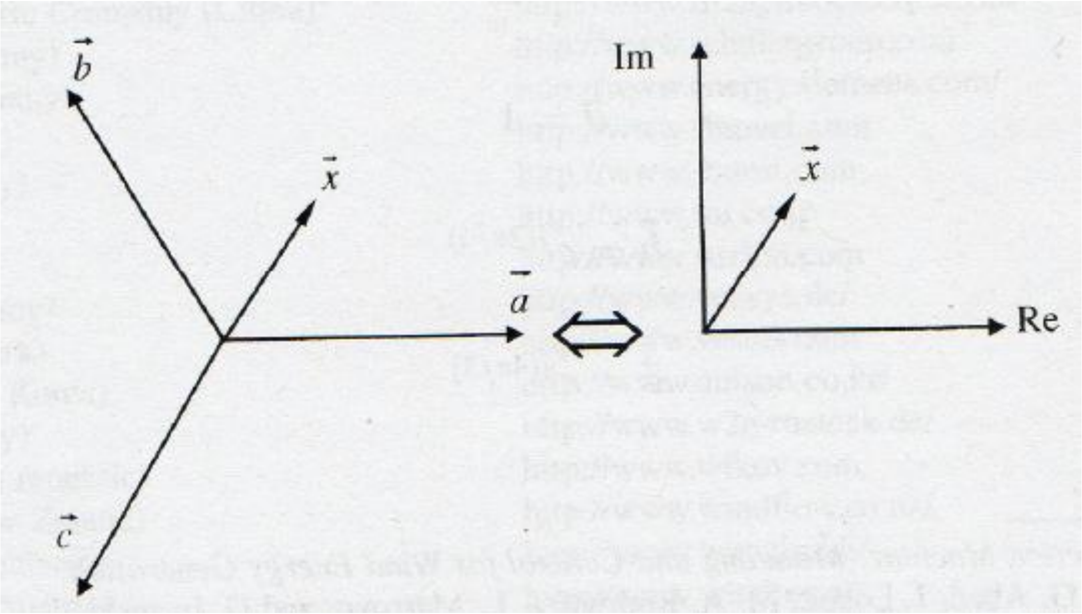
$$\theta = \int_0^t \omega(t)dt + \theta(0).$$

$$(\mathbf{K}_s)^{-1} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta - \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix}.$$

STATIONARY REFERENCE FRAME (CLARKE TRANSFOMATION)



α-β transformation



The α-β components of the space vector can be calculated from the abc magnitudes according to:

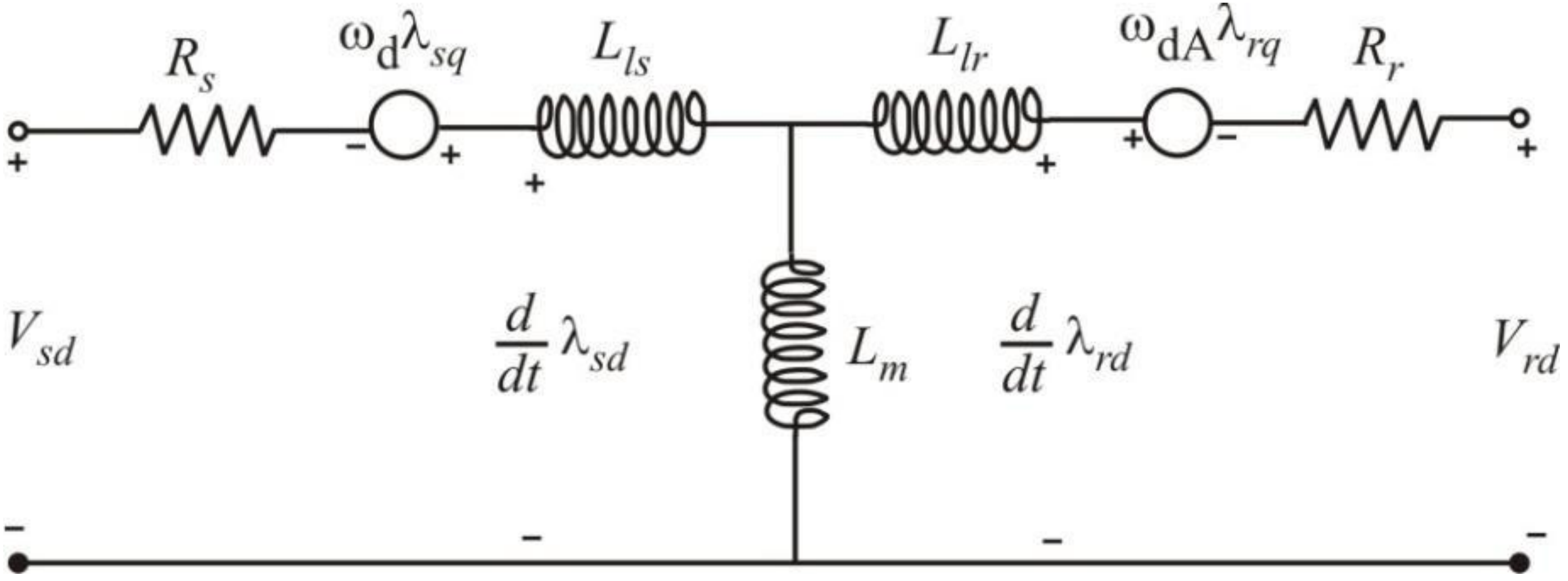
$$\bar{x}_s = x_\alpha + jx_\beta = \frac{2}{3}\left(x_a + ax_b + a^2 x_c\right)$$

$$x_\alpha = \mathrm{Re}\left\{\bar{x}_s\right\} = \frac{2}{3}\left(x_a - \frac{1}{2}x_b - \frac{1}{2}x_c\right)$$

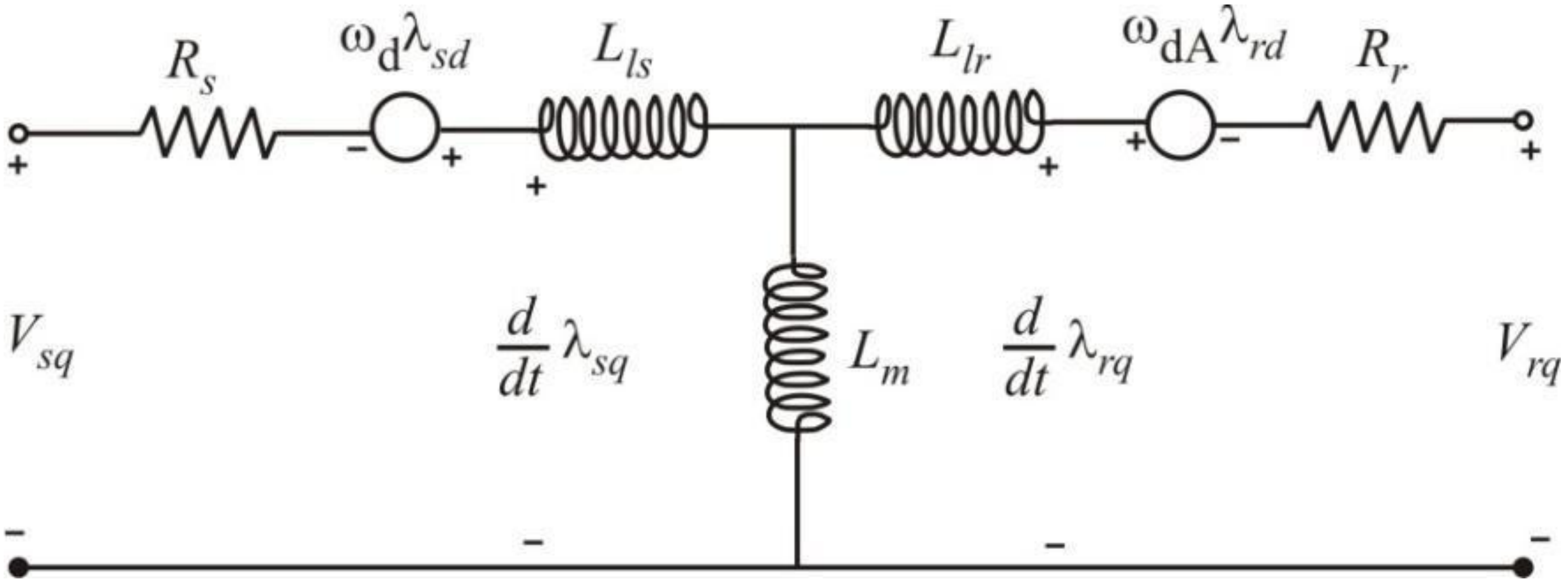
$$x_\beta = \mathrm{Im}\left\{\bar{x}_s\right\} = \frac{2}{3}\left\{\frac{\sqrt{3}}{2}x_b - \frac{\sqrt{3}}{2}x_c\right\}$$

DYNAMIC D-Q MODEL USING PARK'S TRANSFORMATION

IM Equivalent circuit in the *d*-axis frame



IM Equivalent circuit in the *q*-axis frame



$$V_{sa}(t) = R_r i_{ra}(t) + \frac{d\psi_{ra}(t)}{dt}$$

$$V_{sb}(t) = R_r i_{rb}(t) + \frac{d\psi_{rb}(t)}{dt}$$

$$V_{sc}(t) = R_r i_{rc}(t) + \frac{d\psi_{rc}(t)}{dt}$$

The 3-phase stationary reference frame variables *as-bs-cs are transformed into 2-phase stationary reference frame variables (ds–qs). Furthermore, these 2-phase variables are transformed into synchronously rotating reference frame variables (de–qe) and vice-versa. Let us assume that (dS–qs) axes are oriented at an angle of ϑ. The direct axis voltage vsds and quadrature axis voltage vsqs are further resolved into another type of component, viz., as-bs-cs, and finally, writing them in the vector-matrix notation form, we obtain*

$$\begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 1 \\ \cos(\theta - 120^0) & \sin(\theta - 120^0) & 1 \\ \cos(\theta + 120^0) & \sin(\theta + 120^0) & 1 \end{bmatrix} \begin{bmatrix} v_{qs}^s \\ v_{ds}^s \\ v_{os}^s \end{bmatrix}$$

Stationary Reference Frame

$$\bar{i_3} = i_{S\alpha} + j\, i_{S\beta}$$

Where, $$i_{S\alpha} = R_e\left[\frac{2}{3}\,[i_{SA} + a\, i_{SB} + a^2\, i_{SC}]\right]$$

$$i_{S\beta} = I_m\left[\frac{2}{3}\,[i_{SA} + a\, i_{SB} + a^2\, i_{SC}]\right]$$

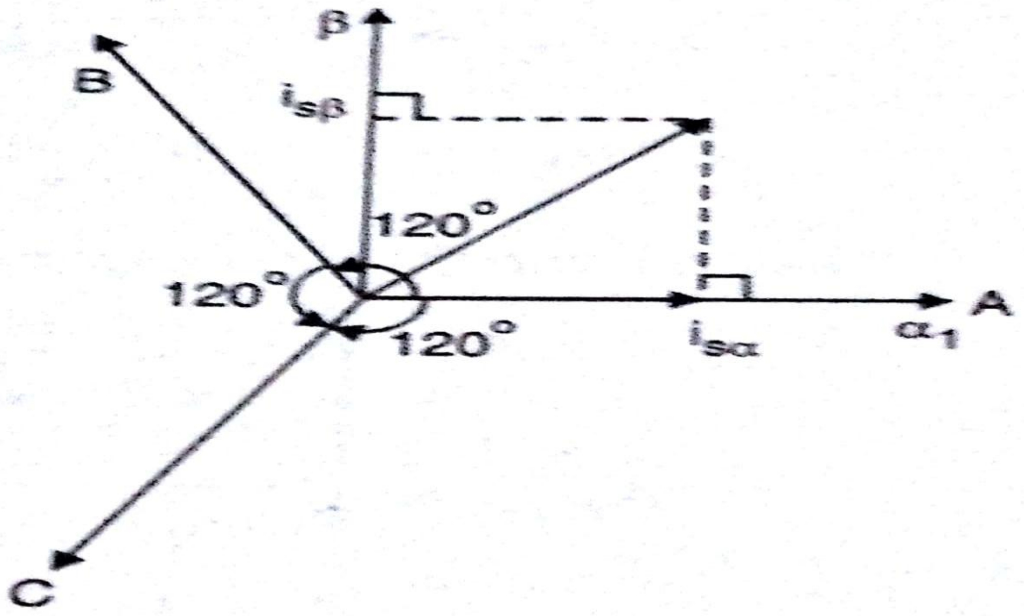
Then, $$i_{S\alpha} = i_{SA}$$

$$i_{S\beta} = \frac{1}{\sqrt{3}}\,(i_{SA} + 2\, i_{SB})$$

$$\begin{bmatrix} i_{S\alpha} \\ i_{S\beta} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ \frac{1}{\sqrt{3}} & \frac{2}{\sqrt{3}} & 0 \end{bmatrix} \begin{bmatrix} i_{SA} \\ i_{SB} \\ i_{SC} \end{bmatrix}$$

The inverse clarke transformation from ab to ABC is

$$\begin{bmatrix} i_{SA} \\ i_{SB} \\ i_{SC} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{S\alpha} \\ i_{S\beta} \end{bmatrix}$$



$$A_W = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{2}{3} & \frac{-1}{3} & \frac{-1}{3} \\ 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \end{bmatrix}$$

$$A_W^{-1} = \begin{bmatrix} 1 & 1 & 0 \\ 1 & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ 1 & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}$$

Assignment

- Why two phase modelling is required for induction motor?
- Why three phase to two phase conversion is required for induction motor?
- Explain matrix of phase conversion with applying KVL.
- Explain ABC reference frame.

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