

Analysis of Electric Machinery and Drive Systems | (3rd Edition)

Chapter 3, Problem 16P

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Step-by-step solution

Step 1 of 11

In order to derive expressions of currents in stationary reference frame and in synchronously rotating reference frame proceed as follows:

In the arbitrary reference frame the expression of current (i_{as}) is given by the following below expressions:

$$i_{as} = \frac{\sqrt{2}V_s}{|Z_s|} \left[-e^{-\frac{t}{\tau}} \cos(\omega t - \alpha) + \cos\left\{(\omega_s - \omega)t - \alpha\right\} \right] \dots\dots (1)$$

Where,

Time constant is τ ,

Electrical angular velocity (ω_s) is 377 rad/s ,

Angular velocity is ω ,

Time is t ,

Phase delay angle is α ,

Voltage (V_s) is $10\sqrt{2} \text{ V}$.

Impedance is Z_s

Also, in the arbitrary reference frame the expression of current (i_{bs}) is given by the following below expressions:

$$i_{bs} = \frac{\sqrt{2}V_s}{|Z_s|} \left[-e^{-\frac{t}{\tau}} \sin(\omega t - \alpha) - \sin\left\{(\omega_s - \omega)t - \alpha\right\} \right] \dots\dots (2)$$

Comment

Step 2 of 11

Now, the expressions for currents in the waveforms shown below in Figure 1 for the stationary reference frame are determined as follows:

ω , rad/s

Figure 1

Comment

Step 3 of 11

It is known that in the stationary reference frame angular velocity (ω) is always zero and $i_{as}^* = i_{as}$, here i_{as}^* stands for quadrature axis current in the stationary reference frame and expression of i_{as} is given below:

$$i_{as} = \frac{\sqrt{2}V_s}{|Z_s|} \left[-e^{-\frac{t}{\tau}} \cos(\alpha) + \cos(\omega_s t - \alpha) \right]$$

As $i_{as}^* = i_{as}$ therefore above expression will transform to the following below expression:

$$i_{as}^* = \frac{\sqrt{2}V_s}{|Z_s|} \left[-e^{-\frac{t}{\tau}} \cos(\alpha) + \cos(\omega_s t - \alpha) \right] \dots\dots (3)$$

Comment

Step 4 of 11

Impedance Z_s is given by the following below expression:

$$Z_s = r_s + j\omega_s L_s$$

$$|Z_s| = \sqrt{(r_s)^2 + (\omega_s L_s)^2}$$

Substitute 0.216Ω for r_s and 1.09Ω in the expression of $|Z_s|$

$$|Z_s| = \sqrt{0.216^2 + 1.09^2}$$

$$= \sqrt{0.1887}$$

$$= 0.434 \Omega$$

As, $\omega_s L_s = 1.09 \Omega$ and $\omega_s = 377 \text{ rad/s}$, the value of inductance (L_s) is determined by the below expression:

$$L_s = \frac{1.09 \Omega}{377}$$

$$= 2.89 \times 10^{-3} \text{ H}$$

Time constant τ is determined by the following below expression:

$$\tau = \frac{L_s}{r_s}$$

Substitute $2.89 \times 10^{-3} \text{ H}$ for L_s and 0.216Ω for r_s in the above expression:

$$\tau = \frac{2.89 \times 10^{-3} \text{ H}}{0.216 \Omega}$$

$$= 0.0133 \text{ H}\Omega^{-1}$$

Comment

Step 5 of 11

The phase delay angle is determined by the following below expression:

$$\alpha = \tan^{-1} \left(\frac{\omega_s L_s}{r_s} \right)$$

Substitute 1.09Ω for $\omega_s L_s$ and 0.216Ω for r_s in the above expression:

$$\alpha = \tan^{-1} \left(\frac{1.09}{0.216} \right)$$

$$= \tan^{-1}(5.046)$$

$$= 78.79^\circ$$

Comment

Step 6 of 11

Substitute the corresponding values in equation (3).

$$i_{as}^* = \frac{\sqrt{2} \{10\sqrt{2}\}}{0.434} \left[-e^{-\frac{t}{0.0133}} \cos(78.79^\circ) + \cos(377t - 78.79^\circ) \right]$$

$$= 46.082 \left[-0.194 e^{-\frac{t}{0.0133}} + \cos(377t - 78.79^\circ) \right]$$

Also, the direct axis current in stationary reference frame (i_{ds}^*) is determined by the following below expressions:

From equation (2).

$$i_{ds} = \frac{\sqrt{2}V_s}{|Z_s|} \left[-e^{-\frac{t}{\tau}} \sin(\omega t - \alpha) - \sin\left\{(\omega_s - \omega)t - \alpha\right\} \right]$$

Substitute $\omega = 0$ in above expression to determine expression for direct axis current in stationary reference frame (i_{ds}^*)

$$i_{ds}^* = \frac{\sqrt{2}V_s}{|Z_s|} \left[-e^{-\frac{t}{\tau}} \sin(-\alpha) - \sin(\omega_s t - \alpha) \right] \dots\dots (4)$$

Comment

Step 7 of 11

Substitute known values in equation (4).

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Hence, the expression of currents in the stationary reference frame are

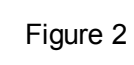
Hence, the expression of currents in the stationary reference frame are

$$i_{ds}^s = 46.082 \left[0.980 e^{\frac{-t}{0.0133}} - \sin(\omega_e t - 78.79) \right].$$

Comment

Step 8 of 11

Now, the expressions for currents in the waveforms shown below in figure 2 for the synchronously rotating reference frame are determined as follows:



It is known that in the synchronously rotating reference frame angular velocity (ω) is always equals to electrical angular velocity (ω_e).

From equation (1)

Substitute $\omega = \omega_r$ in the above expression to determine expression for quadrature axis current in synchronously rotating reference frame (i_q^r).

Step 9 of 11

Substitute corresponding values in equation (5).

Step 10 of 11

Also, the direct axis current in the synchronously rotating reference frame (i_{dh}^*) is determined by the following below expressions:

From equation (2)

Substitute $\omega = \omega_e$ in above expression to determine expression for direct axis current in synchronously rotating reference frame (i_{ds}^e) .

$|\mathcal{L}_s|$

Step 11 of 11

Substitute corresponding values in equation (6).

Hence, the expression of currents in the synchronously rotating reference frame are

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