Answers – Exam 2014. Esbjerg.

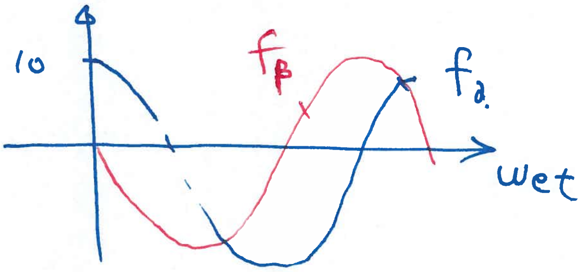
Dynamic modeling of El. machines.

Problem 1.

(1) knowing $\bar{f}_{\alpha\beta} = f_\alpha + j f_\beta$ (the definition).

Now $\bar{f} = 10 e^{-j\omega_e t} = \bar{f}_{\alpha\beta}$

therefore: $\bar{f}_{\alpha\beta} = 10 e^{-j\omega_e t} = 10 [\cos(\omega_e t) - j \sin(\omega_e t)]$



(2) Using the "Vector projection method"

$$f_a = \mathrm{Re}\left(\frac{\bar{f}_{\alpha\beta}}{e^{j0°}}\right) = 10 \cdot \cos \omega_e t.$$

(take the real part) location of phas-a axis

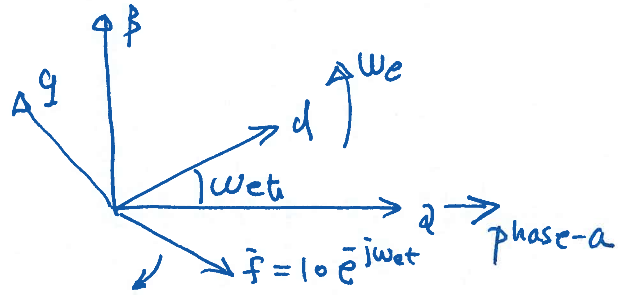
$$f_b = \mathrm{Re}\left(\frac{\bar{f}_{\alpha\beta}}{e^{j120°}}\right) = 10 \cdot \cos(\omega_e t + 120°)$$

location of phase-b axis

$$f_c = \mathrm{Re}\left(\frac{\bar{f}_{\alpha\beta}}{e^{-j120°}}\right) = 10 \cdot \cos(\omega_e t - 120°).$$

What we find is that compared to a normal abc sequence, here, phase-b and phase-c are exchanged.

(3)



this is how the reference frames may be defined.
You can see that at $t=0$, $\omega_e t=0$, and d-axis is alinged with phase-a axis (and the α-axis).

We use the same Vector projection method. Note. for $\bar{f} = 10e^{-j\omega_e t}$, when t increases, it is rotating in a clock-wise (negative) direction.

According to the vector projection method.

$$f_d = Re\left(\frac{\bar{f}_{\alpha\beta}}{e^{j\omega_e t}}\right) = 10\cdot\cos(2\omega_e t) \quad \left(\text{Note. } \bar{f}_{\alpha\beta} = \bar{f} = 10e^{-j\omega_e t}\right)$$

location of the d-axis

$$f_q = Re\left(\frac{\bar{f}_{\alpha\beta}}{e^{j(\omega_e t + 90^\circ)}}\right) = -10\sin(2\omega_e t).$$

You can now sketch their waveforms. The frequency is 100 Hz.

(4) We use the equation.

$$\bar{f}_{\alpha\beta} = \bar{f}_{abc} = \frac{2}{3}\left(V_a + V_b \cdot e^{j\frac{2\pi}{3}} + V_c e^{-j\frac{2\pi}{3}}\right)$$

$$= \frac{2}{3}\cdot V_{pk}\underbrace{\left[\sin(w_e t) + \sin\left(w_e t + \frac{2\pi}{3}\right) e^{j\frac{2\pi}{3}} + \sin\left(w_e t - \frac{2\pi}{3}\right) e^{-j\frac{2\pi}{3}}\right]}$$

The real part of this term

$$= \sin(w_e t) + \sin\left(w_e t + \frac{2\pi}{3}\right)\cdot\cos\frac{2\pi}{3} + \sin\left(w_e t - \frac{2\pi}{3}\right)\cos\frac{2\pi}{3}$$

$$= \sin(w_e t) - \frac{1}{2}\cdot\left[\sin\left(w_e t + \frac{2\pi}{3}\right) + \sin\left(w_e t - \frac{2\pi}{3}\right)\right]$$

$$= \sin(w_e t) - \sin(w_e t)\cdot\cos\frac{2\pi}{3} = \frac{3}{2}\sin(w_e t).$$

The imaginary ~~park~~ part.

$$= \sin\left(w_e t + \frac{2\pi}{3}\right)\sin\frac{2\pi}{3} - \sin\left(w_e t - \frac{2\pi}{3}\right)\cdot\sin\frac{2\pi}{3}$$

$$= \frac{\sqrt{3}}{2}\cdot\left[\sin\left(w_e t + \frac{2\pi}{3}\right) - \sin\left(w_e t - \frac{2\pi}{3}\right)\right]$$

$$= \sqrt{3}\cdot\cos(w_e t)\cdot\sin\frac{2\pi}{3} = \frac{3}{2}\cos(w_e t)$$

Therefore.

$$\bar{f}_{\alpha\beta} = V_{pk}\cdot\frac{2}{3}\cdot\frac{3}{2}\cdot\left[\sin(w_e t) + j\cos(w_e t)\right]$$

$$= V_{pk}\, e^{j\left(w_e t - \frac{\pi}{2}\right)}$$

Then you can do the transformation to other reference frames using the vector projection method.

Problem 3

(1)

The second row $\times -j$ and then plus the first row.

We have:

$$u_{qs} - j u_{ds} = R_s (i_{qs} - j I_{ds}) + p(\lambda_{qs} - j\lambda_{qs}) + w_\theta \lambda_{ds} + j w_\theta \lambda_{qs}.$$

Therefore

$$\bar{U}_{qds} = R_s \bar{I}_{qds} + p\bar{\lambda}_{qds} + j w_\theta \bar{\lambda}_{qds}$$

(Note.. $j w_\theta \bar{\lambda}_{qds} = j w_\theta (\lambda_{qs} - j\lambda_{ds})$
$= w_\theta \lambda_{ds} + j w_\theta \lambda_{qs}.$)

(2) in Steady State, differentiation term of the flux linkage will dissappear. Therefore.

$$\bar{U}_{qds} = R_s \bar{I}_{qds} + j w_\theta \bar{\lambda}_{qds}$$