(1)

The open-circuit terminal voltage of a Y-connected, three-phase, 60-Hz synchronous generator is found to be 13.8 kV rms line-to-line when the field current is 515 A.

a. Calculate the stator-to-rotor mutual inductance L_{af}.

b. Calculate the rms line-line open-circuit terminal voltage for a field current of 345 A and with the generator speed reduced to produce a voltage of frequency 50 Hz.

(2)

In the phasor diagram of three-phase non-salient-pole synchronous machine, there are three couples of EMF and MMF phasors. They are $\dot{E}_0$ and F_{f1}, ________, ________. In these phasors, ________ determines the value of the air gap flux density, $\dot{E}_0$ is the RMS value of ____________.

(3) (Thinking questions, the answer to this question does not need to be submitted)(思考题，此题目可以不提交到网络学堂上)

The armature phase windings of a two-phase synchronous machine are displaced by 90 electrical degrees in space.

a. What is the mutual inductance between these two windings?

b. Repeat the derivation leading to Eq. 5.17 and show that the synchronous inductance is simply equal to the armature phase inductance; that is, $L_s = L_{aa0} + L_{al}$, where L_{aa0} is the component of the armature phase inductance due to space-fundamental air-gap flux and L_{al} is the armature leakage inductance.

Derivation of Eq. 5.17:

When the flux linkages with armature phases a, b, c and field winding f are expressed in terms of the inductances and currents as follows,

$$\lambda_a = \mathcal{L}_{aa} i_a + \mathcal{L}_{ab} i_b + \mathcal{L}_{ac} i_c + \mathcal{L}_{af} i_f \qquad (5.2)$$

$$\lambda_b = \mathcal{L}_{ba} i_a + \mathcal{L}_{bb} i_b + \mathcal{L}_{bc} i_c + \mathcal{L}_{bf} i_f \qquad (5.3)$$

$$\lambda_c = \mathcal{L}_{ca} i_a + \mathcal{L}_{cb} i_b + \mathcal{L}_{cc} i_c + \mathcal{L}_{cf} i_f \qquad (5.4)$$

$$\lambda_f = \mathcal{L}_{fa} i_a + \mathcal{L}_{fb} i_b + \mathcal{L}_{fc} i_c + \mathcal{L}_{ff} i_f \qquad (5.5)$$

5.2.3 Stator Inductances; Synchronous Inductance

With a cylindrical rotor, the air gap geometry is independent of θ_m if the effects of rotor slots are neglected. The stator self-inductances then are constant; thus

$$\mathcal{L}_{aa} = \mathcal{L}_{bb} = \mathcal{L}_{cc} = L_{aa} = L_{aa0} + L_{al} \qquad (5.11)$$

where L_{aa0} is the component of self-inductance due to space-fundamental air-gap flux (Appendix B) and L_{al} is the additional component due to armature-winding leakage flux (see Section 4.10).

The armature phase-to-phase mutual inductances can be found on the assumption that the mutual inductance is due solely to space-fundamental air-gap flux.[1] From Eq. B.26 of Appendix B, we see that the air-gap mutual inductance of two identical windings displaced by α electrical degrees is equal to the air-gap component of their self inductance multiplied by $\cos\alpha$. Thus, because the armature phases are displaced by 120° electrical degrees and $\cos(\pm 120°) = -\frac{1}{2}$, the mutual inductances between the armature phases are equal and given by

$$\mathcal{L}_{ab} = \mathcal{L}_{ba} = \mathcal{L}_{ac} = \mathcal{L}_{ca} = \mathcal{L}_{bc} = \mathcal{L}_{cb} = -\frac{1}{2} L_{aa0} \qquad (5.12)$$

Substituting Eqs. 5.11 and 5.12 for the self and mutual inductances into the expression for the phase-*a* flux linkages (Eq. 5.2) gives

$$\lambda_{\mathrm{a}} = (L_{\mathrm{aa0}} + L_{\mathrm{al}})i_{\mathrm{a}} - \frac{1}{2}L_{\mathrm{aa0}}(i_{\mathrm{b}} + i_{\mathrm{c}}) + \mathcal{L}_{\mathrm{af}}i_{\mathrm{f}} \tag{5.13}$$

Under balanced three-phase armature currents (see Fig. 4.27 and Eqs. 4.25 to 4.27)

$$i_{\mathrm{a}} + i_{\mathrm{b}} + i_{\mathrm{c}} = 0 \tag{5.14}$$

$$i_{\mathrm{b}} + i_{\mathrm{c}} = -i_{\mathrm{a}} \tag{5.15}$$

Substitution of Eq. 5.15 into Eq. 5.13 gives

$$\begin{aligned}\lambda_{\mathrm{a}} &= (L_{\mathrm{aa0}} + L_{\mathrm{al}})i_{\mathrm{a}} + \frac{1}{2}L_{\mathrm{aa0}}i_{\mathrm{a}} + \mathcal{L}_{\mathrm{af}}i_{\mathrm{f}} \\ &= \left(\frac{3}{2}L_{\mathrm{aa0}} + L_{\mathrm{al}}\right) i_{\mathrm{a}} + \mathcal{L}_{\mathrm{af}}i_{\mathrm{f}}\end{aligned} \tag{5.16}$$

It is useful to define the *synchronous inductance* L_{s} as

$$L_{\mathrm{s}} = \frac{3}{2}L_{\mathrm{aa0}} + L_{\mathrm{al}} \tag{5.17}$$

and thus

$$\lambda_{\mathrm{a}} = L_{\mathrm{s}}i_{\mathrm{a}} + \mathcal{L}_{\mathrm{af}}i_{\mathrm{f}} \tag{5.18}$$

Homework 8

1. a. $E_{af} = \frac{13.8}{\sqrt{3}} kV = 7.967 kV$

$$E_{af} = \frac{1}{\sqrt{2}} 2\pi f L_{af} I_f$$

$$L_{af} = \frac{\sqrt{2} E_{af}}{2\pi f I_f}$$

$$L_{af} = \frac{\sqrt{2} \times 7.967 \times 10^3}{2\pi \times 60 \times 515} = 0.058 H$$

b. $E_{af}' = \frac{1}{\sqrt{2}} 2\pi f' L_{af} I_f'$

$$= \frac{1}{\sqrt{2}} 2\pi \times 50 \times 0.058 \times 345$$

$$= 4.445 kV$$

Line to Line : $E_{af}'' = \sqrt{3} \times 4.445 = 7.699 kV$

2. $\dot{E}_a$ and F_a ,

E_δ and F_δ ,

F_δ

no load emf