Fall 2005 EE595S
Homework Assignment Number 3

Note: Since this will not be collected, there is no due date. It is recommended that this be completed before we start the next set of lecture notes.

Problem 1

The turns density of a PMSM is given by $n_{as}(\phi_{sm}) = 162\sin(2\phi_{sm}) - 86.6\sin(6\phi_{sm})$. How many poles does the machine have ? What is the winding function ? (Note: this is the machine that you will be working with in the lab)

Solution

From the $\sin(2\phi_{sm})$ we deduce that the machine had 4 poles. To determine the winding function, we start with

$$\frac{dw_{as}}{d\phi_{sm}} = -n_{as}$$

Thus

$$w_{as} = 80.78\cos(2\phi_{sm}) - 14.43\cos(6\phi_{sm})$$

Problem 2

Starting with (2.2-19) derive (2.2-24), (2.2-28), (2.2-31), and (2.2-32). Note: there is a error in at least one of these equations in the notes.

Solution

Expression (2.2-24) and (2.2-28) are okay as in the text. To derive (2.3-31) and (2.2-32) we start with (2.2-19)

$$\lambda_{as,m} = dr_s P \int_0^{2\pi/P} w_{as}\left(c_{bf}\left(w_{as}i_{as} + w_{bs}i_{bs} + w_{cs}i_{cs}\right) + B_{m,eff}\right)d\phi_{rm}$$

We are interested in the permanent magnet term $\lambda_{as,pm}$, which involves $B_{m,eff}$. In particular

$$\lambda_{as,pm} = dr_s P \int_0^{2\pi/P} w_{as} B_{m,eff}\, d\phi_{rm}$$

Recall that $\phi_r = P\phi_{rm}/2$. Thus

$$\lambda_{as,pm} = 2dr_s \int_0^{\pi} w_{as} B_{m,eff}\, d\phi_r$$

as in the text. Note that in terms of ϕ_r, $B_{m,eff}$ is zero outside the range $(1-\alpha_{pm})\pi/2$ to $(1+\alpha_{pm})\pi/2$. Within this range, $B_{m,eff} = -d_m B_{pm}/(g\mu_{rm} + d_m)$ (a constant). Thus

$$\lambda_{as,pm} = -\frac{dr_s P d_m B_{pm}}{g\mu_{rm} + d_m} \int_{\frac{(1-\alpha_{pm})\pi}{2}}^{\frac{(1+\alpha_{pm})\pi}{2}} w_{as}\, d\phi_r$$

Evaluating the above, we find

$$\lambda_{as,pm} = \lambda_m \sin(\theta_r)$$

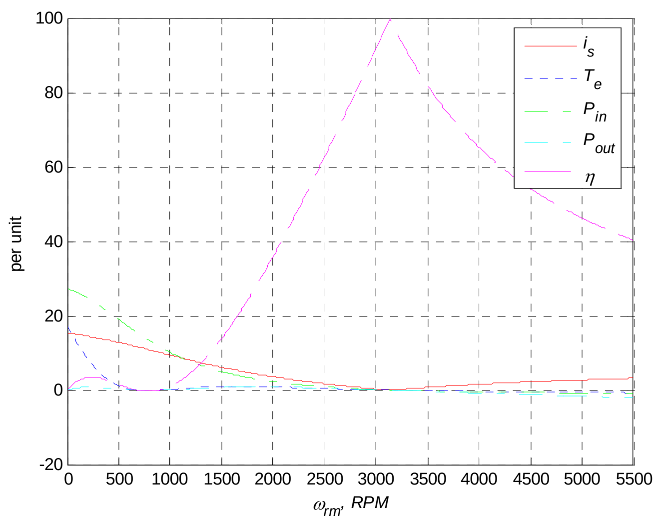
where

$$\lambda_m = \frac{8 n_p d r_s B_{pm}}{P} \sin\left(\pi\alpha_{pm}/2\right) \frac{d_m}{g\mu_{rm} + d_m}$$

Problem 3

Consider the example whose results are in Figure 2.4-1 of Chapter 2 of "Analysis and Design of Permanent Magnet Synchronous Machines". Repeat this example if $L_d = 8$ mH and $L_q = 16$ mH.

Solution



Problem 4

Referring to Chapter 2 of "Analysis and Design of Permanent Magnet Synchronous Machines", suppose the machine is configured as in Fig. 2.5-1. The impedance measured by the LCR meter is 2.5+j10 at 60 Hz. What is L_d ?

Solution

The measured impedance is $Z_m = 2.5 + j10$ at $\omega = 2\pi 60$. The d-axis impedance is given by $Z_d = 2Z_m/3$. Next $L_d = \mathrm{Im}(Z_d)/\omega$. Thus $L_d = 17.7$ mH.

Problem 5

Referring to Chapter 2 of “Analysis and Design of Permanent Magnet Synchronous Machines”, suppose the machine is configured as in Fig. 2.5-1. Could this configuration be used to measure the q-axis parameters ? If so, what would you have to do ?

Solution

Yes. Turn the rotor to $\theta_r = 0$.

Problem 6

The a- to c-phase open circuit voltage of a PMSM is given by $v_{acs} = 200\cos(250t + 0.1)$. Compute λ_m .

Solution

From the radian frequency of the voltage, $\omega_r = 250$ rad/s. For these conditions $200 = \sqrt{3}\omega_r \lambda_m$. Thus $\lambda_m = 0.462$ Vs.

Problem 7

Enumerate the sequence of calculations needed to simulate a PMSM, starting with v_{ag} , v_{bg} , and v_{cg} and ending with the time derivatives of the q- and d-axis currents.

Solution

See course notes