模板虚拟同步机原理

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§1 Modeling Synchronous Machines(by Qing-chang Zhong)

We consider a round rotor machine so that all stator inductance are constant. Our model assumes that there are no damper winding in the rotor, that there is one pair of poles per phase (and one pair of poles on the rotor), and that there are no magnetic-saturation effects in the iron core and eddy currents.As is well known, the damper winding help to suppress hunting and also help to bring the machine into synchronism with the grid.

.The stator windings can be regarded as concentrated coils having self-inductance L and mutual inductance ?M (M>0 with a typical value 1/2L)The field (or rotor) winding can be regarded as a concentrated coil having self-inductance L_f . The mutual inductance between the field coil and each of the three stator coils varies with the rotor angle θ,

$$\begin{aligned} M_{af} &= M_f cos(\Theta) \\ M_{bf} &= M_f cos(\Theta - \frac{2\Pi}{3}) \\ M_{cf} &= M_f cos(\Theta - \frac{4\Pi}{3}) \end{aligned} \tag{1.1}$$

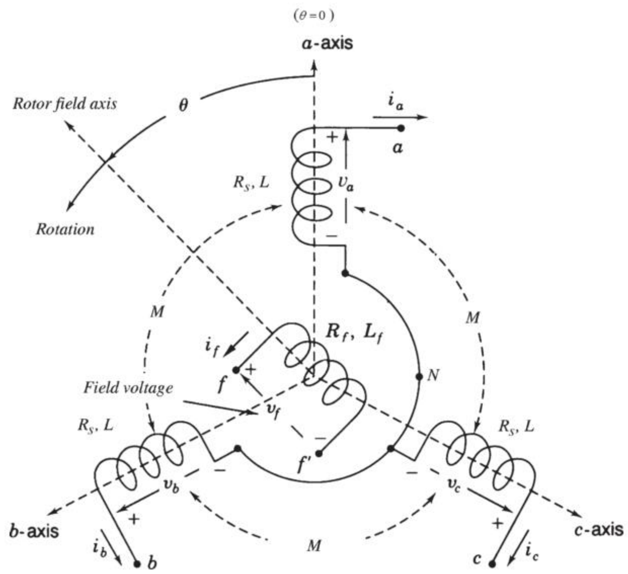

图 1.1 Structure of an idealized three-phase round-rotor SG

so

$$
\begin{aligned}
\Phi_a &= Li_a - Mi_b - Mi_c + M_{af}i_f \\
\Phi_b &= -Mi_a + Li_b - Mi_c + M_{bf}i_f \\
\Phi_c &= -Mi_a - Mi_b + Li_c + M_{bf}i_f \\
\Phi_f &= M_{af}i_a + M_{bf}i_b + M_{cf}i_c + L_fi_f
\end{aligned}
\tag{1.2}
$$

Denote

$$
\Phi = \begin{bmatrix} \Phi_a \\ \Phi_b \\ \Phi_c \end{bmatrix} \qquad i = \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad \tilde{cos}(\Theta) = \begin{bmatrix} cos(\theta) \\ cos(\theta - \frac{2\Pi}{3}) \\ cos(\Theta - \frac{4\Pi}{3}) \end{bmatrix} \qquad \tilde{sin}(\Theta) = \begin{bmatrix} sin(\theta) \\ sin(\theta - \frac{2\Pi}{3}) \\ sin(\Theta - \frac{4\Pi}{3}) \end{bmatrix}
$$

And for the moment that the neutral line is not connected, $i_a + i_b + i_c = 0$ so

$$
\Phi = \begin{bmatrix} L & -M & -M \\ -M & L & -M \\ -M & -M & L \end{bmatrix} i + \begin{bmatrix} M_{af} \\ M_{bf} \\ M_{cf} \end{bmatrix} i_f = \begin{bmatrix} L & -M & -M \\ -M & L & -M \\ -M & -M & L \end{bmatrix} i + M_f i_f \begin{bmatrix} cos(\theta) \\ cos(\theta - \frac{2\Pi}{3}) \\ cos(\Theta - \frac{4\Pi}{3}) \end{bmatrix}
\tag{1.3}
$$

$$\Phi_f = L_f i_f + M_f \begin{bmatrix} i_a & i_b & i_c \end{bmatrix} \begin{bmatrix} cos(\theta) \\ cos(\theta - \frac{2\Pi}{3}) \\ cos(\Theta - \frac{4\Pi}{3}) \end{bmatrix} \tag{1.4}$$

The terminal voltage

$$v = -R_s i - \frac{\mathrm{d}\phi}{\mathrm{d}t} = -R_s i - \begin{bmatrix} L & -M & -M \\ -M & L & -M \\ -M & -M & L \end{bmatrix} \frac{\mathrm{d}i}{\mathrm{d}t} + M_f i_f \omega \begin{bmatrix} sin(\theta) \\ sin(\theta - \frac{2\Pi}{3}) \\ sin(\Theta - \frac{4\Pi}{3}) \end{bmatrix} - M_f \frac{\mathrm{d}i_f}{\mathrm{d}t} \begin{bmatrix} cos(\theta) \\ cos(\theta - \frac{2\Pi}{3}) \\ cos(\Theta - \frac{4\Pi}{3}) \end{bmatrix} \tag{1.5}$$

$$v_f = -R_f i_f - \frac{\mathrm{d}\Phi_f}{\mathrm{d}t} \tag{1.6}$$