无感FOCIF线性磁链观测器

非线性磁链观测器可以快速实现正反转切换;可以观测到极低的转速而不需要强拖启动。但是在零速时带载能力很弱,所以一般情况下还是使用IF开环+速度环闭环控制电机。

非线性磁链观测器的状态变量为磁链值,观测的磁链值收敛于电机实际磁链值,观测器收敛。非线性是由于观测器存在sin和cos项,所以是非线性观测器。

表贴式永磁同步电机alpha-beta轴电压方程如下所示:

$$egin{aligned} egin{aligned} -A_s \\ egin{aligned} egin{aligne$$

将公式变换:

$$Legin{bmatrix} \dot{i_lpha} \ \dot{i_eta} \end{bmatrix} = -R_segin{bmatrix} i_lpha \ \dot{i_eta} \end{bmatrix} + \omega_e\psi_megin{bmatrix} sin heta \ -cos heta \end{bmatrix} + egin{bmatrix} u_lpha \ u_eta \end{bmatrix}$$

定义状态变量:

$$egin{aligned} egin{bmatrix} \dot{x_1} \ \dot{x_2} \end{bmatrix} &= L egin{bmatrix} i_lpha \ i_eta \end{bmatrix} - w_e \psi_m egin{bmatrix} sin heta \ -cos heta \end{bmatrix} = egin{bmatrix} y_1 \ y_2 \end{bmatrix} \ &= -R_s egin{bmatrix} i_lpha \ i_eta \end{bmatrix} + egin{bmatrix} u_lpha \ u_eta \end{bmatrix} \end{aligned}$$

将上述方程积分:

$$egin{bmatrix} x_1 \ x_2 \end{bmatrix} = L egin{bmatrix} i_lpha \ i_eta \end{bmatrix} + \psi_m egin{bmatrix} \cos heta \ \sin heta \end{bmatrix}$$

定义控件向量 eta(x):

$$eta(x) = egin{bmatrix} eta(x_1) \ eta(x_2) \end{bmatrix} = egin{bmatrix} x_1 \ x_2 \end{bmatrix} - L egin{bmatrix} i_lpha \ i_eta \end{bmatrix} = \psi_m egin{bmatrix} cos heta \ sin heta \end{bmatrix}$$

非线性磁链观测器模型:

$$\begin{bmatrix} \dot{\hat{x}}_1 \\ \dot{\hat{x}}_2 \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} + \frac{\gamma}{2} \begin{bmatrix} eta(x_1) \\ eta(x_2) \end{bmatrix} (\psi_m^2 - \|eta(x)\|^2)$$

收敛条件: $\|eta(x)\|^2 = \psi_m^2$

模型离散化:

$$\begin{split} \begin{bmatrix} \hat{x}_{1k} \\ \hat{x}_{2k} \end{bmatrix} &= T_s \left[\begin{bmatrix} y_{1(k-1)} \\ y_{2(k-1)} \end{bmatrix} + \frac{\gamma}{2} \begin{bmatrix} eta(x_1)_{k-1} \\ eta(x_2)_{k-1} \end{bmatrix} (\psi_m^2 - \|eta(x)\|^2) \right] + \begin{bmatrix} \hat{x}_{1(k-1)} \\ \hat{x}_{2(k-1)} \end{bmatrix} \\ \begin{bmatrix} cos \hat{\theta} \\ sin \hat{\theta} \end{bmatrix} &= \frac{1}{\psi_m} \left(\begin{bmatrix} \hat{x}_{1k} \\ \hat{x}_{2k} \end{bmatrix} - L \begin{bmatrix} i_{\alpha} \\ i_{\beta} \end{bmatrix} \right) \end{split}$$

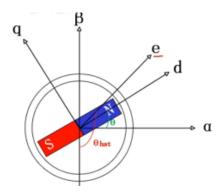
模型离散化:

$$egin{aligned} egin{aligned} egin{aligned} \hat{x}_{1k} \ \hat{x}_{2k} \end{bmatrix} &= T_s \left[egin{aligned} y_{1(k-1)} \ y_{2(k-1)} \end{bmatrix} + rac{\gamma}{2} egin{aligned} eta(x_1)_{k-1} \ eta(x_2)_{k-1} \end{bmatrix} (\psi_m^2 - \|eta(x)\|^2)
ight] + egin{aligned} \hat{x}_{1(k-1)} \ \hat{x}_{2(k-1)} \end{bmatrix} \ egin{aligned} \left[cos \hat{ heta} \ sin \hat{ heta}
ight] &= rac{1}{\psi_m} \left(egin{aligned} \hat{x}_{1k} \ \hat{x}_{2k}
ight] - L egin{aligned} i_lpha \ i_eta \end{bmatrix}
ight) \end{aligned}$$

基于反电动势的PLL:

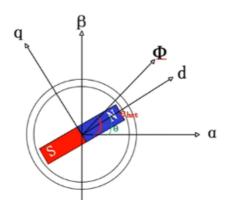
基于反电动势观测器系统观测的是反电动势电压,由于电压经过电感相位相对电流相位超前90°, 故观测器得到的角度需要将90°补偿回来:

实际值: $\hat{ heta}' = \hat{ heta} - \frac{\pi}{2}$, $\hat{ heta}$ 是观测值。



$$sin(\theta - \hat{\theta}) = sin\theta cos\hat{\theta} - cos\theta sin\hat{\theta} = sin\theta cos(\hat{\theta} - \frac{\pi}{2}) - cos\theta sin(\hat{\theta} - \frac{\pi}{2}) = -sin\theta sin\hat{\theta} - cos\theta cos\hat{\theta}$$

基于磁链观测器的PLL:



$$sin(\theta - \hat{ heta}) = sin heta cos\hat{ heta} - cos heta sin\hat{ heta}$$

参考文献

[1] Sensorless Control of Surface-Mount Permanent-Magnet Synchronous Motors Based on a Nonlinear Observer.