## A Real-Time Observer for UAV's Brushless Motors





Vector control has been widely used in control of permanent magnet synchronous motors (PMSM). This technique requires an accurate knowledge of the rotor position. In many applications, such as mini-UAV, it is not possible to install any mechanical sensor. Therefore, a sensorless technique using position observer has to be implemented in order to estimate the rotor position. In this paper, we propose a new observer for PMSM sensorless control: the position estimate is generated upon electromagnetic relations (dynamics of magnetic flux in the motor) in the two-phase stationary reference frame. The implementation of the proposed observer is not a real burden; its validity is experimentally tested and satisfactory results are obtained regarding real position (and speed set-point) tracking in different operating situations.







## **UAV's Brushless Motor Modeling**

The proposed observer is based on electromagnetic equations in the stationary reference frame  $(\alpha\beta)$ . Equations in this reference frame are calculated from 3-phase equations using Clarke Transformation:

## **Parameters Of The Mini-UAV PMSM**



$$v_{\alpha} = Ri_{\alpha} + \frac{d\phi_{\alpha}}{dt}$$

$$= Ri_{\alpha} + L\frac{di_{\alpha}}{dt} - p\phi_{r}\Omega\sin\theta_{e}$$

$$v_{\beta} = Ri_{\beta} + \frac{d\phi_{\beta}}{dt}$$

$$= Ri_{\beta} + L\frac{di_{\beta}}{dt} + p\phi_{r}\Omega\cos\theta_{e}$$

$$i_{\alpha}$$
State Space Model
$$x = \begin{pmatrix} \phi_{\alpha} \\ \phi_{\beta} \end{pmatrix} \longrightarrow \dot{x} = \begin{pmatrix} \frac{d\phi_{\alpha}}{dt} \\ \frac{d\phi_{\beta}}{dt} \end{pmatrix} = \begin{pmatrix} v_{\alpha} - Ri_{\alpha} \\ v_{\beta} - Ri_{\beta} \end{pmatrix}$$

$$= Ax + Bu$$

Parameters	Value [Unit]
Input DC link voltage	12 [V]
Rated output power	90 [W]
Weight	48 [g]
Current / max. 30s	9[A]
Number of pole paires (p)	7
Stator inductance (L)	50 [µH]
Stator resistance (R)	185 $[m\Omega]$
Observer gain $(K_1 = K_2)$	12000

## **Observer Equations** $\frac{d\phi_{\alpha}}{dt} = -K_1\hat{\phi}_{\alpha} + v_{\alpha} - Ri_{\alpha} + K_1\left(Li_{\alpha} + \phi_r\cos\hat{\theta}_e\right)$ $\frac{d\hat{\phi}_{\beta}}{dt} = -K_2\hat{\phi}_{\beta} + v_{\beta} - Ri_{\beta} + K_2\left(Li_{\beta} + \phi_r\sin\hat{\theta}_e\right)$ **Position and Speed Estimation**

$$u = \begin{pmatrix} v_{\alpha} - Ri_{\alpha} \\ v_{\beta} - Ri_{\beta} \end{pmatrix} \qquad A \text{ is null and } B = [1, 1]^T$$

$$y = \begin{pmatrix} Li_{\alpha} \\ Li_{\beta} \end{pmatrix} \longrightarrow \hat{y} = \begin{pmatrix} \hat{Li}_{\alpha} \\ \hat{Li}_{\beta} \end{pmatrix} = \begin{pmatrix} \hat{\phi}_{\alpha} - \phi_r \cos \hat{\theta}_e \\ \hat{\phi}_{\beta} - \phi_r \sin \hat{\theta}_e \end{pmatrix}$$
$$= C\hat{x} + f(\hat{\theta}_e)$$

**Observer Synthesis** 

$$\frac{d\hat{x}}{dt} = A\hat{x} + Bu + K\left(y - \hat{y}\right)$$





The proposed observer presents many advantages : > it is a minimal order observer that depends on electrical dynamics only ➢its implementation is not a real burden > it is able to start the motor using sensorless closed-loop control >gain tuning is done with respect to current closed-loop response time