Sampled Data High Gain Observer Design Combined with State Predictor For Synchronous PMSMs
A.A.R Al Tahir, Fouad Giri, Tarek Ahmed-Ali

To cite this version:
hal-01465330

HAL Id: hal-01465330
https://hal.archives-ouvertes.fr/hal-01465330
Submitted on 18 Feb 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Introduction

- This work is devoted to Sampled Data High Gain Observer design for a class of uniformly observable systems.
- The design of nonlinear observers with sampled measurements has received great attention.
- This interest is motivated by many applications such as Networks Communication Systems.
- Recently, a hybrid samples data observer dedicated of a class of nonlinear systems has been presented.
- This approach is based on an inter sample time predictor, which estimates the output between two sampling instants.
- The advantage of this algorithm is in the fact that the state estimates remain continuous time model.
- At each sampling instant, the predictor is reset to the actual output.
- This work presents observer with sampled data measurements and his application to a surface permanent magnet synchronous motor.

Modelling and Observability Study of Synchronous PMS Machines

Because the rotor position is not supposed to be available, the PMSM model is considered in the (α-β) frame :

- The objective is to determine under what conditions all the state of the SPMSM motor, is \( l_r \), \( o_{m} \), and \( T_C \) can be determined from the output and input measurements, namely the current and the voltage measurements \( i_s \) and \( u \), respectively.

\[
\frac{\text{d}l_s}{\text{d}t} = \left[ \begin{array}{c} \frac{1}{\lambda} \cos(\phi) \frac{\text{d}\phi}{\text{d}t} + \frac{1}{\lambda} \sin(\phi) \frac{\text{d}l_r}{\text{d}t} \\ \frac{1}{\lambda} \sin(\phi) \frac{\text{d}\phi}{\text{d}t} + \frac{1}{\lambda} \cos(\phi) \frac{\text{d}l_r}{\text{d}t} \\ \end{array} \right]
\]

The mechanical rotor position is \( \theta_{r} = \frac{1}{p} \tan^{-1} \left( \frac{\omega_0}{\phi_{m}} \right) \).

Now, let us consider the following change of state variables:

\[ \Phi : \mathbb{R}^6 \to \mathbb{R}^6, x \to z = \left( \begin{array}{c} Z_1 \\ Z_2 \\ Z_3 \\ \end{array} \right) = \Phi(x) = \left( \begin{array}{c} \Phi_1(x) \\ \Phi_2(x) \\ \Phi_3(x) \end{array} \right) \]

Let \( J_\Phi \) be the Jacobian of \( \Phi(x) \). According to (6), one has:

\[ J_\Phi(x) = \left[ \begin{array}{ccc} I_2 & 0_2 & 0_2 \\ 0_2 & \delta\Phi_2(x) / \delta x_1 & \delta\Phi_2(x) / \delta x_2 \\ 0_2 & \delta\Phi_3(x) / \delta x_1 & \delta\Phi_3(x) / \delta x_2 \\ \end{array} \right] \]

It is clear that the matrix \( J_\Phi(x) \) is of full rank if and only if the following square matrix is also of full rank:

\[ G_\Phi(x) = \left( \begin{array}{cc} \delta\Phi_2(x) / \delta x_1 & \delta\Phi_2(x) / \delta x_2 \\ \delta\Phi_3(x) / \delta x_1 & \delta\Phi_3(x) / \delta x_2 \end{array} \right) \]

\[ \det G_\Phi(x) = \det(G1G4 - G3G2) \]

Then, the considered transformation has a full rank in each x as soon as:

\[ x_{31}x_2^2 \neq 0 \] or in the original motor variables, \( \psi_l \omega_m \neq 0 \) the following dynamical system is an observer

\[ \hat{x} = f(x,u) - \theta_{\Phi}(x)D \theta_{\Phi}^{-1}K(C(x) - w(t)) \]

\[ w(t) = y(t) + v(t) \]

Maximum Allowable Sampling Period \( T_{MSP} \):

**Theorem 1**: Under assumptions (A1- A2), system (22) is a sampled data observer for system (16) with the following property: For sufficiently large values of parameters \( \theta \) and \( k_i = 1:23 \), there exists a real positive bounded \( T_{MSP} \) such that for all \( r \in (0, T_{MSP}) \), the observation error is ultimately bounded and the corresponding ultimate bound can be made as small as desired by choosing values of \( \theta \) high enough.

- We derive a condition on the maximum allowable sampling period that ensures a convergence of the observation error.

\[ T_{MSP} = \lim_{r \to 0} \left( \frac{1}{\theta} \left( \frac{1}{\phi_{m}} - \frac{1}{\phi_{m}} \right) + \frac{1}{\phi_{m}} \right) \]

- Then, the observer is exponentially stable whatever the initial conditions. The error vector \( e_r = \hat{x}(t) - x(t) \) converges exponentially to a compact neighborhood of the origin and the size of this compact set can be made small by choosing the design parameters \( \theta \) sufficiently large.

Mathematical Results:

- The simulation results illustrate that the proposed SDHGO observer has fast transient response, good external load torque rejection response accurate tracking response and accurate recovery from any external disturbance.

Simulation Results:

- The simulations illustrate the performance of the proposed observer in terms of state estimation accuracy, tracking performance and robustness against external disturbances.

Experimental Results:

- The experimental results confirm the theoretical findings and demonstrate the effectiveness of the proposed observer in practical applications.

Table 1: Mechanical and Electrical Characteristics of a Surface Mounted PMSM.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Power (kW)</td>
<td>10</td>
</tr>
<tr>
<td>Rated Voltage (V)</td>
<td>380</td>
</tr>
<tr>
<td>Rated Current (A)</td>
<td>300</td>
</tr>
<tr>
<td>Rated Speed (rpm)</td>
<td>1500</td>
</tr>
<tr>
<td>Stator Resistance (Ω)</td>
<td>0.1</td>
</tr>
<tr>
<td>Inertia (kgm²)</td>
<td>0.02</td>
</tr>
<tr>
<td>Back EMF (V/°)</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 2: Synchronous Motor Parameters for SPMSM.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator Inductance</td>
<td>0.1 mH</td>
</tr>
<tr>
<td>Field Inductance</td>
<td>0.2 mH</td>
</tr>
<tr>
<td>Stator Resistance</td>
<td>0.01 Ω</td>
</tr>
<tr>
<td>Field Resistance</td>
<td>0.02 Ω</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>0.005 Ω</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>0.008 Ω</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>0.003 Ω</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>0.002 Ω</td>
</tr>
</tbody>
</table>

Fig. 1: Line Diagram of Proposed Case Study of SPMSM.