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Original article

Dynamic identification of a synchronous machine using an extended sliding mode observer

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Abstract

This paper presents two identification methods for permanent magnet synchronous machine based on sliding modes. The first one is a new algorithm obtained from an identification technique based on an extended sliding mode observer and a least square solution using an instrumental variable. The second approach uses a direct identification algorithm using a sliding mode observer. Both techniques are tested in simulation and applied in experimentation on a synchronous motor. A comparison study is done in the aim of enhancing their performances.

Keywords: Nonlinear identification; Synchronous machine; Sliding modes; Extended observer; Instrumental variable

1. Introduction

Power machine identification is still a challenging problem because most of their models are nonlinear with time varying unknown parameters. The mechanical aspect of these systems and the difficulty to identify this part provide another reason to take an interest in this identification field. Permanent magnet synchronous machines (PMSMs) have been the subject of parameter estimations for many years. Park's transformation and the two axis equivalent circuit give the opportunity to have a model with a linear parameter structure. For this reason, techniques for linear systems have been applied on the PMSM like the least-square estimation or error prediction methods. Several papers in the literature can be found as [2,3,5,15]. One can remark that most of these works restrict the identification to the electrical parameters and do not deal with the mechanical parameters, which is due to the difference of speed convergence between the slow modes (mechanical) and the fast ones (electrical). Another point that must be highlighted is the identification robustness to measurement noise. This problem has been seldom taken into account during the estimation algorithm development is up until now.

The scope of this paper is to identify synchronous machine parameters using two robust online identification techniques based on sliding modes. Both electrical and mechanical parameters are estimated simultaneously and the speed convergence is controlled to maintain a balance between the convergence of the different dynamic modes. The application on a real process and the comparison study reveal the efficiency of the proposed methods.

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Nomenclature

x	state vector
n	state vector dimension
θ	parameter vector
r	parameter vector dimension
u	control vector
m	control vector dimension
Φ	regressor matrix
$\hat{x}$	estimated state vector
$\hat{\theta}$	estimated parameter vector
K	gain matrix
$\tilde{x}$	state error vector
$\tilde{\theta}$	parameter error vector
$\hat{\tilde{\theta}}$	estimated parameter error vector
θ_{nom}	nominal parameter vector
ϵ	bounded noise
Γ	dynamic gain matrix
x_{IV}	auxiliary model state vector
Φ_{IV}	instrumental variable matrix
K_θ	gain diagonal square matrix
θ_x	state parameter vector
θ_u	control parameter vector
λ	positive constant
R_s	stator resistance
L	stator inductance
φ_f	magnetic flux
J	moment of inertia
f	viscous friction coefficient
I_d, I_q	direct and quadrature currents
V_d, V_q	input voltages
Ω	mechanical velocity
C_r	load torque
p	number of pole pairs

The article is organized as follows: The first section presents the PMSM model in Park's work frame. The next two sections introduce the proposed approaches. The following section shows the application of those techniques on the machine model in simulation. Finally, the last section is dedicated to the experimental results and a comparison study.

2. First approach: instrumental variable – sliding mode (IVSM) identification

Consider the following class of nonlinear systems:

$$\dot{x} = \Phi^T(t, x, u)\theta + F(t, x) \tag{1}$$

where $x \in n\mathfrak{R}$ is the measurable state vector, $u \in m\mathfrak{R}$ is the control vector and $\theta \in r\mathfrak{R}$ is the vector of unknown time-invariant parameters. The following assumptions are made:

(i) x, u and Φ are continuous and bounded.
(ii) x is measured.