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ScienceDirect
Mathematics and Computers in Simulation 119 (2016) 18–34
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Original articles

Sliding mode controller of hydraulic generator regulating system based on the input/output feedback linearization method

Xiaohui Yuan[a], Zhihuan Chen[a], Yanbin Yuan[b,*], Yuehua Huang[c], Xianshan Li[c], Wenwu Li[c]

[a] *School of Hydropower and Information Engineering, Huazhong University of Science and Technology, 430074, Wuhan, China*
[b] *School of Resource and Environmental Engineering, Wuhan University of Technology, 430070, Wuhan, China*
[c] *College of Electrical Engineering and New Energy, China Three Gorges University, 443002, Yichang, China*

Received 11 October 2014; received in revised form 14 April 2015; accepted 30 August 2015
Available online 7 September 2015

Highlights

- The nonlinear hydraulic generator regulating system (HGRS) model is studied.
- This kind of HGRS system considers the external disturbances and system uncertainty.
- The input/output feedback linearization method is used to establish the relationship.
- Sliding mode controller (SMC) is applied to adjust the orbit output of HGRS system.
- PID controller is employed to the adjustment process in HGRS system as a comparison.

Abstract

An input/output feedback linearization method based sliding mode control strategy is proposed for the hydraulic generator regulating system (HGRS) with external disturbance and system uncertainties to enhance its response. Based on the input/output feedback linearization method, the relationship between reference output and control output is established. Then a sliding mode controller is designed to reject the influence of external disturbance and system uncertainties on the system performance and compelled the current dynamic output exponentially stabilized at their reference states. In order to eliminate the inherent harmful chattering phenomenon of sliding mode controller, a high-slope saturation function is used to replace the discontinuous sign function in the sliding mode manifold design. Several simulations with respect to the dynamic analysis of HGRS system without controller, fixed point stabilization, periodic orbit tracking and robustness test against random noises have been carried out to test the effectiveness of the proposed controller technique. The results show that the proposed sliding mode controller improves the nonlinear HGRS system performance with an accurate precision and a shorter time in all cases.

Keywords: Input/output feedback linearization; Sliding mode; Hydraulic generator regulating system; External disturbance; System uncertainties

* Corresponding author. Tel.: +86 13627242159.
E-mail address: yuanyanbin_whut@163.com (Y. Yuan).

http://dx.doi.org/10.1016/j.matcom.2015.08.020

Nomenclature

HGRS:

•	hydraulic series
m_t	turbine mechanical torque relative deviation
q	turbine flow rate relative deviation
y	guide vane relative deviation
h	water head deviation
x	turbine speed relative deviation
ex, ey, eh	partial derivatives of turbine torque with respect to the turbine speed, guide vane and water head
eqx, eqy, eqh	partial derivatives of turbine flow with respect to the turbine speed, guide vane and water head
u	output of controller
T_w	water starting time
T_y	major servomotor response time
•	electrical series
δ	generator rotor angle relative deviation
ω	generator speed relative deviation
T_a	generator mechanical time constant
D	generator damping constant
m_e	generator electromagnetic torque
P_e	generator electromagnetic power
E'_d	generator transient voltage of d-axis
V_s	generator voltage of infinite bus system
$x_{d\Sigma}$	generator direct axis reactance
x'_d	generator transient direct axis reactance
x_T	short-circuit reactance of transformer
x_L	reactance of transmission lines
$x_{q\Sigma}$	generator quadrature axis reactance
x_q	synchronous reactance of quadrature axis

L&D of HGRS:

d	the uncertain system state perturbation, namely $d = \begin{bmatrix} d_1 & d_2 & d_3 & d_4 \end{bmatrix}^T$
X	the system state vector, namely $X = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \end{bmatrix}^T = \begin{bmatrix} \delta & \omega & m_t & y \end{bmatrix}^T$
Y	the current system output vector, namely $Y = x_2$
$Y_d(t)$	the desired (reference) trajectory output vector, namely $Y_d(t) = x_2^*$
L&D	linearization and decoupling
$A(x)$	the assisted L&D construction control item
B	the assisted L&D construction item, which is limited in a certain range, i.e. $\|B\| \leq D_r$

Controller:

•	PID controller
kp	proportional adjustment coefficient
ki	integral adjustment coefficient
kd	differential adjustment coefficient
•	SMC controller
s	the designed sliding mode manifold
c	a positive constant of sliding mode control
η	a positive constant of assisted item (larger than D_r)
$\mathrm{sgn}(s)$	sign function
sat	a high-slope saturation function (approaching $\mathrm{sgn}(s)$)
ξ	a small constant