energies

MDPI

Article

Load Frequency Regulator in Interconnected Power System Using Second-Order Sliding Mode Control Combined with State Estimator

Anh-Tuan Tran [1], Bui Le Ngoc Minh [2,3], Van Van Huynh [1,*], Phong Thanh Tran [1], Emmanuel Nduka Amaefule [1], Van-Duc Phan [4] and Tam Minh Nguyen [2]

1 Modeling Evolutionary Algorithms Simulation and Artificial Intelligence, Faculty of Electrical & Electronics Engineering, Ton Duc Thang University, Ho Chi Minh City 700000, Vietnam; trananhtuan.st@tdtu.edu.vn (A.-T.T.); tranthanhphong.st@tdtu.edu.vn (P.T.T.); ndukaamaefuleemmanuel.st@tdtu.edu.vn (E.N.A.)
2 Faculty of Electrical and Electronics Engineering, Ho Chi Minh City University of Technology and Education, Ho Chi Minh City 700000, Vietnam; 1726002@student.hcmute.edu.vn (B.L.N.M.); tamnm@hcmute.edu.vn (T.M.N.)
3 Faculty of Industrial Engineering, Tien Giang University, My Tho City 840000, Vietnam
4 Faculty of Automobile Technology, Van Lang University, Ho Chi Minh City 700000, Vietnam; duc.pv@vlu.edu.vn
* Correspondence: huynhvanvan@tdtu.edu.vn

Abstract: In multi-area interconnected power systems (MAIPS), the measurement of all system states is difficult due to the lack of a sensor or the fact that it is expensive to measure. In order to solve this limitation, a new load frequency controller based on the second-order sliding mode is designed for MAIPS where the estimated state variable is used fully in the sliding surface and controller. Firstly, a model of MAIPS integrated with disturbance is introduced. Secondly, an observer has been designed and used to estimate the unmeasured variables with disturbance. Thirdly, a new second-order sliding mode control (SOSMC) law is used to reduce the chattering in the system dynamics where slide surface and sliding mode controller are designed based on system states observer. The stability of the whole system is guaranteed via the Lyapunov theory. Even though state variables are not measured, the experimental simulation results show that the frequency remains in the nominal range under load disturbances, matched and mismatched uncertainties of the MAIPS. A comparison to other controllers illustrates the superiority of the highlighted controller designed in this paper.

Keywords: load frequency control; multi area power system; sliding mode control

check for updates

Citation: Tran, A.-T.; Minh, B.L.N.; Huynh, V.V.; Tran, P.T.; Amaefule, E.N.; Phan, V.-D.; Nguyen, T.M. Load Frequency Regulator in Interconnected Power System Using Second-Order Sliding Mode Control Combined with State Estimator. *Energies* **2021**, *14*, 863. https://doi.org/10.3390/en14040863

Academic Editor: Muhammad Aziz
Received: 15 January 2021
Accepted: 4 February 2021
Published: 7 February 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

In modern multi-area power systems (MAPS), where the power plants are geographically distributed, maintaining the tie-power flow and frequency are the central aspects of the MAPS. At sudden change in the net load, frequency and tie-schedule power deviate from nominal. Therefore, it is essential to preserve the quality of the generated power in the power plant through designing a load frequency control (LFC) [1–6]. The general function of the LFC is to maintain the balance between the new net-load demand and the generated power by regulating the tie-line and frequency power flow in MAPS.

In general, power plants are connected together via tie-lines. Maintaining scheduled power flows between interconnected large systems is very crucial. Moreover, keeping the frequencies of each area in a nominal range where the plant model exhibits the following drawbacks: random load change, and mismatched uncertainties. These made the LFC design more complex [7]. Thus, two approaches are used for LFC in the interconnected power network: a centralized and decentralized LFC scheme where the second scheme is preferable as the controller feed-in by the regional information [8–10].