ARTICLE IN PRESS

Engineering Science and Technology, an International Journal xxx (2018) xxx–xxx

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Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: www.elsevier.com/locate/jestch

Full Length Article

Application of adaptive-SOS (ASOS) algorithm based interval type-2 fuzzy-PID controller with derivative filter for automatic generation control of an interconnected power system

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ARTICLE INFO

Article history:
Received 10 November 2017
Revised 19 March 2018
Accepted 19 March 2018
Available online xxxx

Keywords:
Automatic generation control
Fuzzy logic based controllers
Type-2 fuzzy logic system
Symbiotic organism search algorithm
Adaptive symbiotic organism search algorithm

ABSTRACT

In this article, a maiden comparative performance analysis of interval type-2 fuzzy-PID controller with & without derivative filter (T2FPIDF & T2FPID), type-1 fuzzy-PID controller (T1FPID) and conventional PID controller for Automatic Generation Control (AGC) in a two area interconnected thermal power system is presented. The proposed controllers are optimally designed using a novel adaptive symbiotic organism search (ASOS) & symbiotic organism search (SOS) optimization techniques. Symbiotic organism search (SOS) algorithm is established from the interrelation of organisms to survive in the ecosystem and in this article it is modified by using self-tuned benefit factors. This makes the ASOS superior over SOS. To prove the superiority of ASOS algorithm over SOS algorithm and T2FPIDF controller over other proposed controllers, transient performance of the AGC system is studied by applying a sudden step load change of 10% in area-1 of the two unequal area power system. Various transient parameters such as undershoot, overshoot and settling time are considered to carry out the performance analysis study. Robustness analysis is performed by varying all the system parameters to prove the effectiveness of the proposed controller against parametric variation. Finally it observed that ASOS optimized T2FPIDF controller outperforms other proposed controllers in terms of less undershoot, overshoot and settling time.

1. Introduction

In power system, one of the biggest constraints is to balance generated, transmitted and distributed active powers. An undesirable asynchronism between generated power and demanded power arises due to unforeseen disturbances and load perturbations may cause the system frequency to vary from its nominal value [1,4]. Primary or inertial and secondary or automatic generation controls (AGC) are two categories of frequency control. Primary controller helps to damp out large frequency deviations in power system. Whereas secondary controller or AGC helps in regulating the control valve position of turbine to shorten the inequality between the system frequency and its nominal value, and to maintain the tie-line power exchange between areas at its scheduled value.

Interconnection of various generating units is essential to provide reliable, uninterrupted and economic power to customers. Traditional Load frequency control (LFC) greatly involves, when frequency deviations in all interconnected areas considerably influences due to sudden switching of load in any area [2,3].

Primary purposes of LFC are as follows:

i. Counterbalance the system under abrupt load disruption.
ii. Minimize undershoot, overshoot and settling time of frequency oscillations and tie-line power deviations of a broad interconnected power system.
iii. Reduce the area control error (ACE) to zero as quickly as possible.

Literature review concedes that Cohn [2] introduced load frequency control of interconnected power system with tie line bias control in 1957. Optimal control of interconnected power system with conventional controllers (I, PI, ID, PID and IDD) as AGC is introduced by Elgerd and Fosha [3] in 1970. Many researchers have worked to enhance the capability of conventional controllers by optimizing the gain parameters with numerous optimization techniques in the literatures [4–11]. BFOA, DE, GA and Hybrid BFOA–PSO optimized PI controller for AGC in

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Peer review under responsibility of Karabuk University.

https://doi.org/10.1016/j.jestch.2018.03.010
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interconnected thermal systems is proposed in references [4–6,50]. Khodabakhshian et al. [6] have provided a comparative analysis of PID over PI controller for AGC in hydropower system. 2 DOF PID controller optimized by Cuckoo Search and TLBO algorithm for a three area reheat thermal power system is proposed in references [8,9]. To improve the performance of classical controllers, Cascade combinations of P, I and D controllers (PD-PID and PI-PD) optimized by FPA and BA have been used in [10,11]. R.K. Sahu et al. [12,13] implemented hybrid GA-PS and hybrid FA-PS algorithms to optimize PID and PIDF controllers to enhance the transient response of AGC.

In 1965 Zadeh [14] introduced fuzzy sets and based on fuzzy theory, fuzzy logic based controllers are designed and implemented successfully in many research fields. Fuzzy logic based controllers are designed and implemented in AGC of different power systems in references [15–17]. Yeşil et al. [18] presented the comparative performance analysis of a self-tuned FPID controller and a conventional PID controller to deal with the AGC issues in a two area interconnected power system. Ghoshal [19] presented optimal design of PID controller using various stochastic search algorithms like PSO, GA, HPSO and GSA for fuzzy logic based AGC of a three area interconnected thermal power system. FPID controller with different membership functions suitable for various AGC systems tuned by various conventional and hybrid optimization algorithms are presented in literatures [20–25,48]. To enhance the sensitiveness of detection of load disturbance, FPID controller with derivative filter is described in [26,52]. Many authors have proposed to merge artificial neural network with fuzzy interface system to enhance the dynamic performance of AGC system [27–29] and emotional based optimized neuro-fuzzy is described in [49]. A novel NCS algorithm optimized controller in interconnected power system with DFIG based wind plant is portrayed admirably in [53]. The interconnected hydro-thermal system with redox flow battery is further substantiated in deregulated environment with OARs [54]. Theory and design of Interval type-2 fuzzy logic systems is reported in references [30–32].Wu [33] proposed three different methods for type-reduction of interval type-2 fuzzy logic system to reduce the computational cost and burden. Applications of different optimization techniques to obtain optimal solution of type-2 fuzzy systems are reported by [34,35].

This research article deals with the design and implementation of T2FPIDF, T2FPID, T1FPID, and conventional PID controller to improve the transient performance of AGC system for a two area four unit thermal power system. Gains of these controllers are optimally designed ASOS and SOS optimization algorithms. Step load change of 10% is applied in area1 of the power system to study the dynamic responses of various controllers. Finally a comparative performance analysis of various controller and ASOS and SOS algorithm is presented. Main features of this article are as follows:

i. Development of a two unequal area four unit thermal power system in MATLAB Simulink environment.
ii. Design of T2FPIDF, T2FPID, T1FPID and conventional PID controllers in MATLAB Simulink environment for AGC of the proposed power system.
iii. Implementation of ASOS and SOS algorithm.
iv. Optimal design of the proposed controllers using ASOS and SOS algorithms.

2. Power system model

The proposed interconnected power system consists of two unequal areas and each area is having two thermal units with different characteristics. Transfer function model of the power system is shown in Fig. 1. Each thermal generating unit with its governor and turbine is represented with its equivalent transfer functions.

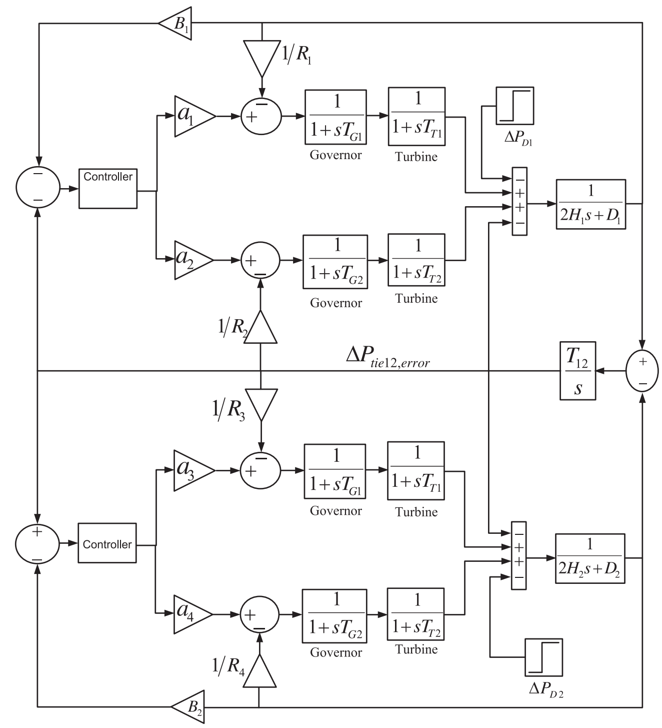

Fig. 1. Transfer function model of the two unequal area four unit interconnected power system.

Step load change (ΔP_D) of 0.1pu (10%) is applied in area-1 to observe the dynamic performance of the power system. Area control errors (ACEs) in both areas linearly depend on frequency deviation of the respective area and tie-line power deviation. T2FPIDF, T2FPID, T1FPID, and conventional PID controllers are implemented in each area of the power system. The prime objective of these controllers is to minimize the ACEs. ACEs of each area (ACE) are given by

$$ACE_1 = \Delta P_{tie,1-2} + B_1 \Delta f_1 \quad (1)$$

$$ACE_2 = \Delta P_{tie,2-1} + B_2 \Delta f_2 \quad (2)$$

Suffix 1 and 2 are used to indicate the parameters of area-1 and area-2 respectively. B_1 and B_2refers to the frequency bias factors in area-1 and area-2 respectively. Δf_1 and Δf_2 are the frequency deviations of respective areas. ΔP_{tie} is the real power exchange between two areas and can be determined by Eq. (3)

$$\Delta P_{tie,1-2} = \frac{T_{12}}{s} + (\Delta f_1 - \Delta f_2) \quad (3)$$

T_{12} is the time constant of interconnected tie-line. Various parameters of the power system shown in Fig. 1 are given in Appendix. ACEs are used as input signal to controllers and outputs of controllers are used as input signals to the thermal power system.

3. Optimal design of proposed controllers

This article presents optimal design and implementation of type-2 fuzzy-PID controller with derivative filter (T2FPIDF), type-2 fuzzy-PID controller without derivative filter (T2FPID), type-1 fuzzy-PID controller (T1FPID) and conventional PID controller. Inputs to these controllers are the area controller and outputs are fed to generating units. Structure of these proposed controllers