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A hybrid chemical reaction-particle swarm optimisation technique for automatic generation control

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Abstract

In this paper, a novel hybrid chemical reaction optimisation and particle swarm optimisation (HCROPSO) optimised PI controller has been proposed for automatic generation control (AGC) problem. A two area reheat thermal-hydro system with non-linearities such as governor dead band (GDB), generation rate constraints (GRC) and boiler dynamics is considered. The parameters of PI controller are optimised employing HCRO-PSO technique. The superiority of the proposed approach is shown by comparing the results with PSO, CRO and fuzzy logic control (FLC). Improvement in system performance is obtained in terms of reduced settling time, overshoot and undershoot of frequency deviation and tie line power deviation with proposed controller. Investigation is performed with variation in inter rate and inertia weight parameters. Sensitivity analysis is performed by varying the system parameters and generation rate constraints from their nominal values. Analysis reveals that HCRO-PSO optimized PI gains obtained at nominal are quite robust and need not be reset for wide changes in system parameters.

Keywords: Chemical reaction optimisation (CRO); Particle swarm optimisation (PSO); Governor dead band (GDB); Generation rate constraints (GRC)

1. Introduction

The Load Frequency Control (LFC) has been one of the major issues in electric power system design, operation and control. It is becoming much more significant recently in accordance with increasing size, changing structure and complexity of modern interconnected power systems. Providing reliable and good quality of power is a challenging task in modern power systems. In this regard, LFC plays an important role, as the primary objective of LFC is to maintain system frequency and tie-line power oscillations within the specified limits. A healthy power system should therefore be designed, to accommodate system disturbances without hampering the generated power, while maintaining the system

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Nomenclature

$ACE_{1,2}$	Area control errors
$B_{1,2}$	Frequency bias constant of area
ΔF	Incremental change in frequency (Hz)
$\Delta Ptie$	Change in tie line power connecting between area (p.u)
f	Nominal system frequency (Hz)
Kr	Gain of the reheat turbine
$K_{PS(1,2)}$	Power system gain (Hz/puMW)
$R_{1,2}$	Governor speed regulation parameter of Generation station (Hz/pu MW)
T_W	Nominal starting time of water in penstock (s)
T_1	Hydro turbine speed governor reset time (s)
T_2	Hydro turbine speed governor transient droop time constant (s)
T_{G2}	Hydro turbine speed governor main servo time constant (s)
$T_{PS(1,2)}$	Power system time constant (s)
T_{12}	Synchronizing coefficients
T_{G1}	Speed governor time constant of thermal unit (s)
T_{T1}	Turbine time constant of thermal unit (s)
Tr	Time constants of the reheat turbine
$u_{1,2}$	Are the control outputs form the controller

frequency and tie line power oscillations within the specified limits. To achieve the objective of LFC, many researchers work on automatic generation control (AGC) with different intelligent techniques and different controllers. Elgerd and Fosha (1970) reported modern optimal control for an interconnected AGC. Kothari et al. (1989) proposes a discrete controller with a new Area Control Error (ACE) for a multi-area system with reheat turbines. A robust decentralized controller has been proposed for AGC system by Yang et al. (1998). Khodabakhshian et al. (2012) demonstrated sequential quadratic programming to design robust load frequency control. Ghoshal (2004) applied the Particle Swarm Optimization (PSO) algorithm based on fuzzy to obtain gains of proportional integral derivative (PID) controller in AGC. Some researcher proposed controllers for multi area AGC using fuzzy logic based gain scheduling (Chang and Fu, 1997; Cam and Kocaarslan, 2005), neural network (Wu et al., 1992; Chaturvedi et al., 1999; Demiroren et al., 2001; Zeynelgil et al., 2002; Imthias Ahamed et al., 2002), adaptive neuro-fuzzy interface system (ANFIS) approach (Hosseini and Etemadi, 2008; Khuntia and Panda, 2012). Gozde and Taplamacioglu (2011) have employed a Craziness based PSO (CRAZYPSO) to obtain gain of PI controller for a two-area thermal power system AGC having governor dead-band nonlinearity. Ali and Abd-Elazim (2011) have reported that, proportional integral (PI) controllers tuned with the help of Bacterial Foraging Optimization Algorithm (BFOA), provides better performance as compared to that with GA based PI controller in two-area non-reheat type thermal systems. Differential evolution (DE) algorithm is Q4 also employed in two-area thermal AGC system to search the parameters of 2-Degree of freedom PID controller (Sahu et al., 2013).

Each controller has its own advantages and disadvantages, such as linear optimal controller is sensitive to variation in the plant parameters and operating condition of power systems. Training of an ANN and ANFIS is a major exercise, because it depends on various factors such as the availability of sufficient and accurate training data, suitable training algorithm, number of neurons in the ANN and number of ANN layers. Design of a fuzzy based controller requires more design decision than usual, for example, regarding the number of membership functions, their shape, and their overlap for all inputs and outputs, rule base, inference engine, defuzzification, and pre and post processing of data. Therefore, ANN, ANFIS and fuzzy logic based controllers suffer from the requirement of expert user in their design and implementation, and mathematical rigors and so are vulnerable to the experts' depth of knowledge in problem definition. The PI and PID is the most popular feedback controller used in the process industries. It is a robust, easily understood controller that can provide excellent control performance despite the varied dynamic characteristics of process plant.

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