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Teaching–learning based optimization algorithm based fuzzy-PID controller for automatic generation control of multi-area power system

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ABSTRACT

This paper deals with the design of a novel fuzzy proportional–integral–derivative (PID) controller for automatic generation control (AGC) of a two unequal area interconnected thermal system. For the first time teaching–learning based optimization (TLBO) algorithm is applied in this area to obtain the parameters of the proposed fuzzy-PID controller. The design problem is formulated as an optimization problem and TLBO is employed to optimize the parameters of the fuzzy-PID controller. The superiority of proposed approach is demonstrated by comparing the results with some of the recently published approaches such as Lozi map based chaotic optimization algorithm (LCOA), genetic algorithm (GA), pattern search (PS) and simulated algorithm (SA) based PID controller for the same system under study employing the same objective function. It is observed that TLBO optimized fuzzy-PID controller gives better dynamic performance in terms of settling time, overshoot and undershoot in frequency and tie-line power deviation as compared to LCOA, GA, PS and SA based PID controllers. Further, robustness of the system is studied by varying all the system parameters from −50% to +50% in step of 25%. Analysis also reveals that TLBO optimized fuzzy-PID controller gains are quite robust and need not be reset for wide variation in system parameters.

1. Introduction

An interconnected power system should generate, transport and distribute the electric energy at nominal system frequency and terminal voltage. But system frequency depends upon the balance between the generated active power and the active power that is consumed [1]. Due to sudden disturbances or some other reasons if the generated active power becomes less than the power demand, the frequency of generating units tends to decrease and vice versa. This causes the system frequency to deviate from its nominal value which is undesirable. To damp out the frequency deviation quickly and to keep the tie-line power at its scheduled value, Automatic generation control (AGC) concept is used. AGC plays a vital role in power system in maintaining nominal frequency and scheduled tie-line power flow during normal operating condition as well as under small perturbations. The design of AGC system for each generating unit eventually controls the system frequency and tie-line power flow between different control areas of an interconnected power system. Therefore AGC plays a vital role in automation of power system. Nuclear units are generally used to supply base load because of their high efficiency and they do not take part in automatic generation control. Gas power generation is a small percentage of the total power generation and is suitable to supply the varying power demand. Hydro power plants operate with various constraints like water availability and regulations. However the role of AGC cannot be avoided in thermal power systems.

Literature survey reveals that, early works on automatic generation control was introduced by Cohn [2] in 1957. In 1970 the concept of modern optimal control for AGC in an interconnected power system was introduced by Elgerd [3]. The gain scheduling control method for AGC of interconnected power system was proposed by Lee et al. [4]. Talaq and Al-Basri [5] have suggested an adaptive fuzzy gain scheduling method for conventional PI controller. Pingkang et al. [6] have optimized the gains of PI and PID controllers using real coded genetic algorithm in a two-area interconnected power system. Maldonado et al. [7] have used PSO to

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optimize interval type-2 fuzzy controller. Melin et al. [8] have used a new chemical optimization paradigm to optimally design type-2 and type-1 fuzzy controller to track autonomous mobile robots. Castillo and Melin [9] have presented a review of different methods used to interval type-2 fuzzy controller. Castillo et al. [10] have proposed a new design methodology of type-2 fuzzy models. Valdez et al. [11] have presented a comprehensive review of some optimization techniques in which parameter adaptation is taken care by fuzzy logic. Melin et al. [12] have developed a new method to adjust the social and cognitive parameters (c_1 and c_2) of PSO using fuzzy logic. Valdez et al. [13] have proposed a new optimization technique combining GA and PSO in which fuzzy logic is used to combine the results of GA and PSO in best possible way. Castillo et al. [14] have described the use of hierarchical genetic algorithms to optimize fuzzy logic in the area of intelligent control. Abdel-Magid and Abido [15] have proposed the tuning of AGC for an interconnected reheat thermal system using PSO. Yesil et al. [16] have suggested the self-tuning fuzzy-PID type controller for AGC. Gozde and Taplamacioglu [17] have used Artificial Bee Colony (ABC) optimization algorithm to study the dynamic performance of AGC in a two-area interconnected thermal power system. Nanda et al. [18] have used Bacterial Foraging (BF) optimization algorithm to determine several important parameters of interconnected three unequal area thermal systems. Abraham et al. [19] have presented the analysis of AGC of a hydrothermal interconnected system with generation rate constraints (GRCs). Ali and Abd-Elazim [20] have used bacteria foraging optimization technique to obtain the optimum gains of a PI controller. Abraham et al. [21] have analyzed AGC of two-area interconnected hydrothermal power system by taking thyristor controlled phase shifter (TCPS) in series with the tie line. Rout et al. [22] have applied differential evolution algorithm to determine the gains of a PI controller for AGC of a two-area interconnected system. A hybrid BFOA-PSO technique is employed in [23] to tune the PI controller parameters of two and three-area power system.

In this paper the dynamic performance of a fuzzy-PID controlled AGC system for a two-area interconnected thermal power system has been studied. Classical techniques of determining the optimum gains of the fuzzy-PID controller may fail to give optimal solution while solving harder constrained problems with large number of variables or in a large search space. Previous research works in many area related to fuzzy-PID controller have selected the input and output scaling factors of the controller after going through several hit and trial runs. The performance of the controller mainly depends on the proper selection of these parameters and it is very difficult to get the optimum values using hit and trial method.

The main contribution of the work is to use a fuzzy-PID controller for AGC of a two unequal area interconnected thermal system with input and output scaling factors optimized by a recently developed optimization technique called Teaching–learning based optimization (TLBO) algorithm proposed by Rao et al. [24,25].

Performance of many optimization techniques depends on proper selection of certain control parameters. For example, GA [26] needs mutation rate and crossover rate, PSO [27,28] uses the inertia weight (w), social and cognitive parameters (C_1 and C_2), DE [29,30] uses scaling factor (F) and crossover rate (CR), etc. Selection of these parameters plays a very crucial role in the performance of the algorithms. However teaching–learning based optimization (TLBO) algorithm does not require any controlling parameter. Since it is a parameter free algorithm, it is simple, effective and faster which motivates many researchers to use this algorithm in their own research area.

Therefore, TLBO technique is used for the first time in this area and also proved to be performing better in terms of settling time, overshoot and undershoot than other optimization techniques such as Lozi map based chaotic optimization algorithm (LCOA), genetic algorithm (GA), pattern search (PS), and simulated annealing (SA) [31].

2. Two-area power system model

A fuzzy-PID controlled two unequal area interconnected non-reheat type thermal power system is shown in Fig. 1 [31]. It consists

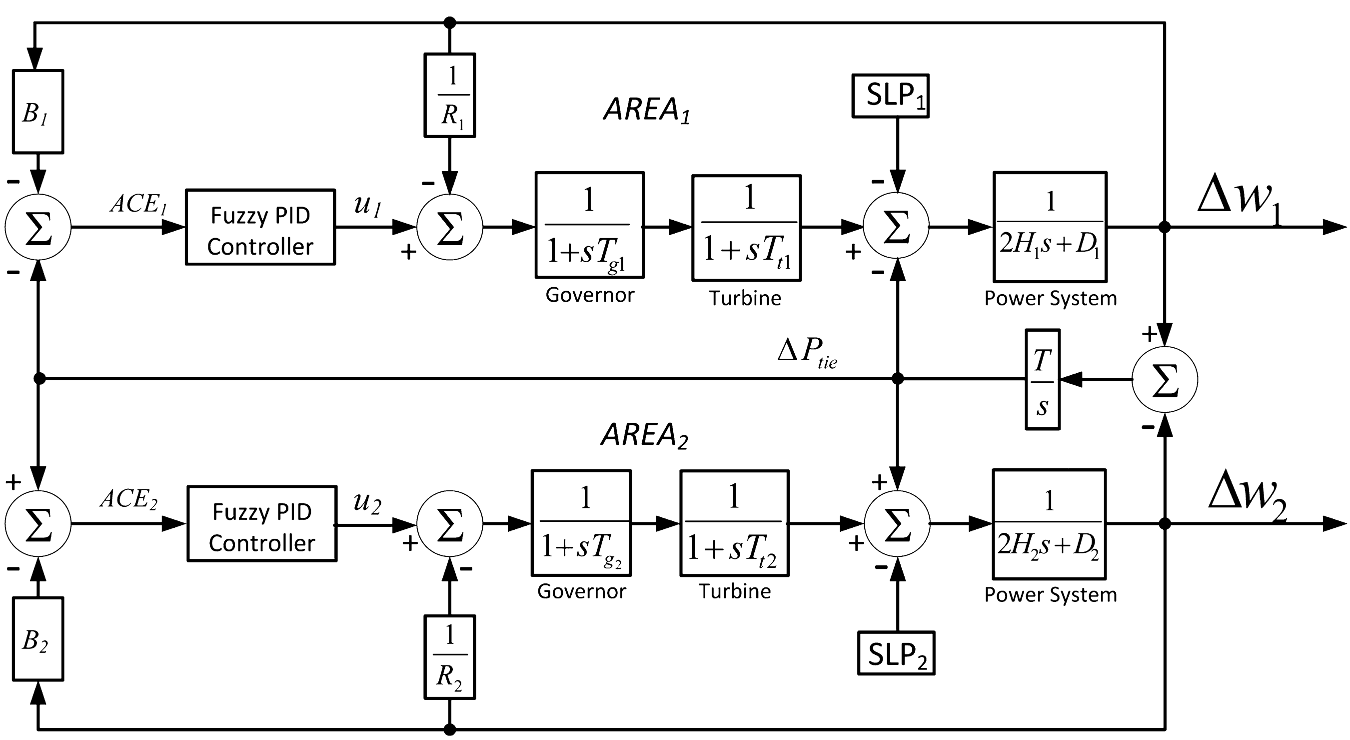

Fig. 1. Transfer function model of the two-area interconnected thermal system [31].