Development of a Fractional Order PID Controller for a Physical System based on Bat Inspired Algorithm

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Abstract—This paper proposes the optimal design of FOPID controller by the bat inspired algorithm (BIA). The Integral square error (ISE) criterion has been invoked to tune the FOPID controller. The FOPID controller has five parameters K_p, K_d, K_i, λ *and* μ.In the first approach, two identical FOPID controllers are applied. The $K_p, K_d,$ and K_i parameters of each controller have been optimized using the particle swarm optimization (PSO). The rest of parameters λ *and* μ for each area have been determined using the BIA. In the second approach, two different controllers have been applied. The $K_p, K_d,$ and K_i parameters for each controller have been estimated using PSO technique. So, we aim to determine 4 parameters $\lambda_1, \mu_1, \lambda_2,$ *and* μ_2 using the BIA. The simulation results show that the proposed FOPID controller based on BIA using the second approach exhibits improved dynamic performance over conventional PID controller and the FOPID controller based on BIA using the first approach.

Index Terms *-Bat inspired algorithm (BIA), Load Frequency Control (LFC), Fractional order PID (FOPID) controller, power systems.*

I. INTRODUCTION

In the last decade, fractional-order dynamic systems and controllers has been studying widely in many areas of engineering and science [1-5]. The concept of the fractional-order PID (FOPID) controller was proposed by Podlubny [6]. He also demonstrated the better response of this type of controllers, in comparison with the classical PID controllers, when used for the control of fractional-order systems. He was demonstrated the major role of fractional-order calculus in a smart mechatronic system [7]. Hardware and digital realizations of fractional-order systems can be followed in [8, 9, 10]. A frequency domain approach based on given phase margin and crossover frequency is studied in [11]. In [12] an optimization method is presented such that predefined design specifications are satisfied. A method is presented based on the pole distribution of the characteristic equation in the complex plane [13]. A state-space design approach is presented based on feedback pole placement in [14]. A method is presented based on differential evolution (DE) technique in [15]. Also, a method is presented based on idea of the Ziegler–Nichols and the Astrom–Hagglund methods in [16]. A method is presented based on the asymptotic behavior of fractional algebraic equations and applies a delicate property of the root loci of the system in [16]. A fractional order controller is designed to improve the flight control performance of a small fixed-wing unmanned aerial vehicle (UAV) in [17]. In [18] a fractional order controller for AVR system is presented based on a new criterion function with eight terms by use of particle swarm optimization (PSO). In [19] by applying Mean of Root of Squared Error (MRSE), Mean of Absolute Magnitude of the Error (MAE) and Mean Minimum Fuel and Absolute Error (MMFAE) as fitness function, Fractional PID Controllers Using PSO Algorithm for Robot Trajectory Control is tuned.

This paper proposes the bat inspired algorithm (BIA) for optimal tuning of FOPID controller in single area power system to damp power system oscillations. The FOPID controller design is formulated as an optimization problem and BIA is employed to search for optimal controller parameters by minimizing a candidate time-domain based objective function. The performance of the proposed FOPID -based BIA is evaluated by comparison with PID-based BIA and conventional PID controller. Simulations results on a single-area test system are presented to assure the superiority of the proposed method compared with PID-based BIA and conventional one.

II.PROBLEM STATEMENT

One of the control problems in power system operation is to maintain the frequency and power interchange between the areas at their rated values. The mechanical power is produced by a turbine and delivered to a synchronous generator feeding the demand load. The frequency of the synchronous generator is mainly affected by the load demand. If, for example, the electrical load is suddenly increased, the generator shaft slow down, and the frequency of the generator decreases. Thus, the control system must immediately handle the load variation and command the control valve to open more so that the turbine increases its mechanical power production, matches the incremental load demand and returns the rotor speed to its rated value and therefore the generator frequency. Fig. 1 shows a schematic diagram of load frequency control operation [20].

To achieve this control action, LFC monitors the system frequency and tie-line flows in each area, computes the net change in the generation required (referred as Area Control Error-ACE) and changes the set point of the generators within the area so as to keep the time average of the ACE at a low value, thus ACE, which is the linear combination of power net-interchange and frequency deviation, is taken as the controlled output of LFC [21]. Both frequency and tie-line power errors will be forced to zero as the ACE is driven to zero by the LFC [22].

III. The Conentional PID Controller

PID controller is considered to be a key component of industrial control system because of its capability of improving the dynamic response of the system and reducing the steady state error. PID controller involves three parameters K_p , K_i and K_d where K_p depends on the present error, K_i depends on accumulation of past errors and K_p is a prediction of future errors based on current rate of change. The transfer function for the PID controller is

$$C(s) = K_p + \frac{K_i}{s} + K_d s \qquad (1)$$

IV. FRACTIONAL ORDER CONTROLLERS ($PI^{\lambda}D^{\mu}$)

The concept of a fractional order PID control system is explained by [7, 23]. Fractional order PID controller (FOPID) form is represented mathematically as follows :