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Optimization of PID Controller based on PSOGSA for an Automatic Voltage Regulator System

Supol Kansit* and Wudhichai Assawinchaichote

Department of Electronic and Telecommunication Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

Abstract

This paper presents an optimal Proportional Integral Derivate (PID) controller design for an Automatic Voltage Regulator (AVR) system using a new hybrid devised from the Particle Swarm Optimization and the Gravitational Search Algorithm (PSOGSA). The transient response analysis and bode analysis were considered to show the effectiveness of the design technique. Moreover, the comparison of the results between the proposed approach and other techniques such as the Ziegler-Nichols (ZN) tuning method, the Particle Swarm Optimization (PSO) tuning method and the Many Optimizing Liaisons (MOL) tuning method have been given. According to the analysis, the proposed PSOGSA algorithm gives better results than other techniques for the AVR system.

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Keywords: Automatic Voltage Regulator, Particle Swarms Optimization and Gravitational Search Algorithm, PID Controller.

1. Introduction

The Automatic Voltage Regulator (AVR) system is widely applied in power system networks, that is usually used for improving power quality and eliminating relevant issues for the electric power systems. However, the AVR system has problems with inefficient oscillated transient response, a maximum overshoot, steady-state errors. These problems can be solved by creating a closed loop system with the AVR system and the controller.

Currently, there are various controllers that can be used. However, one of the controller that is very simple and effective is the Proportional Integral Derivate (PID) controller. The advantage of a PID controller is that it can provide the robust performance for a wide range of operating conditions. It can also reduce the dynamic range error, eliminate

* Corresponding author. Tel.: +66-819-248-372; fax: +66-228-788-49.
E-mail address: supol.ka@mail.kmutt.ac.th

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the steady-state error and improve in the transient response of loop back functions system. However, for the best results, some techniques need to be implemented for PID gains to converge so that the system is optimal.

The Particle Swarm Optimization and Gravitational Search Algorithm (PSOGSA) method can solve the optimization problems of the PID controller. The PSOGSA is a low level co-evolutionary heterogeneous hybrid technique of the Particle Swarm Optimization (PSO) work together with the Gravitational Search Algorithm (GSA). This algorithm was motivated by merging social thinking ability in the PSO and the ability of local search in the GSA for a faster convergence speed and a better searching capability for a global optimum.

The objective of this paper is to implement a PSOGSA for searching optimal parameters on the PID controller for the AVR system. A desired peak amplitude, settling time, rise time and peak time are obtained by minimizing the objective function which is the Integral Time multiplied by the Absolute Error (ITAE). The result is then compared with the result of the Ziegler-Nichols (ZN), the Particle Swarm Optimization (PSO) and the Many Optimizing Liaisons (MOL) tuning method[1] to show that proposed algorithm gives better than other techniques.

2. Mathematical Modeling of an AVR System

The AVR system has the function to improve the quality of the electrical power by maintaining the terminal voltage output of the generator at a desired level. When the terminal voltage output has an error voltage occurrence, a sensor will detect and compare the error with a reference voltage for the error difference. It is then amplified by an amplifier and is used to control the generator with an exciter[2]. A simple linearized AVR system model consists of amplifier, exciter, generator and sensor. The transfer function of the AVR system given by:

$$\frac{\Delta V_t(s)}{\Delta V_{ref}(s)} = \frac{0.1s+10}{0.0004s^4+0.0454s^3+0.555s^2+1.51s+11} \tag{1}$$

This system has a peak amplitude of 1.5 volts or in other words is a maximum overshoot of 65.4%, a rise time of 0.261 seconds, a settling time of 6.970 seconds and a steady-state at 0.909.

3. Overview of Particle Swarm Optimization and Gravitational Search Algorithm

The PSOGSA This algorithm was hybridized from the Particle Swarm Optimization (PSO) and the Gravitational Search Algorithm (GSA). It was proposed by Seyedali Mirjalili and Siti Zaiton Mohd Hashim in 2010. They are used in parallel to find the optimal result[3]. The PSOGSA steps are as specified below.

Step 1: Initialization of the agent's random positions.

$$X_i = (x_i^1, \ldots x_i^d, \ldots x_i^n) \qquad ;\ for\ \ i = 1, 2, \ldots N \tag{2}$$

where x_i^d represents the position of the agent i in the d dimension while n is the space dimension.

Step 2: Computation of the fitness evolution for all agents with the appropriated objective function.

Step 3: Calculation of the gravitational constant, mass, force and acceleration of each agent by:

$$G(t) = G_0^{-\alpha \frac{t}{t_{\max}}} \tag{3}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{i=1}^{N} m_i(t)} \tag{4}$$

$$F_i^d(t) = G(t) \times \left(\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t)} \right) \times \left(x_j^d(t) - x_i^d(t) \right) \tag{5}$$

$$ac_i^d(t) = \frac{F_i^d(t)}{M_i(t)} \tag{6}$$