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GA Base tuning of the PID Control of an Automatic Voltage Regulator (AVR) System

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ABSTRACT

This paper addresses a robust method for optimal PID control of automatic Voltage Regulation (AVR) system to damp terminal voltage oscillation following disturbances in power systems. The optimization is carried out by the genetic algorithm Optimization (GA) to improve their situation. The optimal tuning problem of the PID gains to control of AVR system against parametric uncertainties is formulated as an optimization problem according to time domain based objective function. It is carried out under multiple operation conditions to achieve the desired level of terminal voltage regulation. The results analysis reveals that the GA based PID type AVR control system is effective and provides good terminal voltage oscillations damping ability.

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INTRODUCTION

In recent years, the scale of power systems has been expanded, and with that stability and constancy of nominal voltage level in an electric power grid is becoming more important. One of method for increasing stability and achieving nominal voltage level in an electric power grid is raising the voltage or employing series capacitors in power transmission lines, but controlling of generator exciter by using of Automatic Voltage Regulator (AVR) is attracting attention because of its inherent cost advantage (Saadat,1999). The generator excitation system maintains generator voltage and controls the reactive power flow using an automatic voltage regulator (D.H. Kim, J.H. Cho, 2006). The task of an AVR system is to hold the terminal voltage magnitude of a synchronous generator at a specified level. Thus, the stability of the AVR system would seriously affect the security of the power system. Despite the potential of the modern control techniques with different structure, Proportional Integral Derivative (PID) type controller is still widely used for AVR system (V. Mukherjee, S.P. Ghoshal,2007). This is because it performs well for a wide class of process. Also, they give robust performance for a wide range of operating conditions and easy to implement. On the other hand, Mukherjee and Ghoshal(Z.L. Gaing,2004) have presented a comprehensive analysis of the effects of the different PID controller parameters on the overall dynamic performance of the AVR system. It is shown that the appropriate selection of PID controller parameters results in satisfactory performance during system upsets. Thus, the optimal tuning of a PID gains is required to get the desired level of robust performance. Since optimal setting of PID controller gains is a multimodal optimization problem (i.e., there exists more than one local optimum) and more complex due to nonlinearity, complexity and time-variability of the real world power systems operation. Hence, local optimization techniques, which are well elaborated upon, are not suitable for such a problem(Gozde, M.C. Taplamacioglu,2010).

In this study, the problem of robustly PID gains tuning is formulated as an optimization problem based on time do-main based objective function. The optimization is carried out under multiple operation points by Genetic algorithm such that the relative stability is guaranteed and the time domain specifications concurrently secured.

Results evaluation show that the proposed method is effective and alternative to PID fixed gain controller design as it retains the simplicity of the controller and still guarantees a robust acceptable performance over a wide range of operating and system conditions.

GA Based Tuning of the PID Controller Gains

Introduction to Genetic Algorithm PID:

In 1975, GA was proposed firstly by Holland (Moghaddas, M., M. Reza Dastranj, N. Changizi, and N. Khoori,2012). It is an optimization algorithm and applied to various fields, including business, science, and

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engineering. Based on the survival-of-the-fittest strategy proposed by Darwin, this algorithm will eliminate unfit components to select the fittest component by Man-made fitness functions generation by generation.

A. Initialization:

In the initialization, the first thing to do is to decide the coding structure. Coding for a solution, termed a chromosome in GA literature, is usually described as string of symbols from $\{0, 1\}$. These components of the chromosome are then labeled as genes. The number of bits that must be used to describe the parameters is problem dependent.

B. Selection:

GA uses proportional selection; the population of next generation is determined by n independent random experiments.

C. Crossover:

Cross over is an important random operator in GA and the function of this operator is to generate a new 'child' chromosome from two 'parents' chromosomes by combining the information extracted from the parents.

D. Mutation:

Mutation is another important component in GA, though it is usually conceived as a background operator. It operates independently on each individual by probabilistically perturbing each bit string. A usual way of mutation used in GA is to generate a random number between zero and one and then make a random change in the v -th element of the string with probability p_m belonging to $(0, 1)$.

E. Encoding & Decoding:

The design variables are mapped onto a fixed-length binary Digit string, which are constructed over the binary alphabet $\{0,1\}$, and is concatenated head-to-tail to form one long string referred as a chromosome. That is, every string contains all design variables. The physical values of the design variables are obtained by decoding the string.

F. Fitness Function:

In GA, the value of fitness represents the performance, which is used to rank the string, and the ranking is used to determine how to allocate reproductive opportunities. This means that individuals with higher fitness value will have higher probability of selection as a parent. Fitness thus is some measure of goodness to be optimized. The fitness function is essentially the objective function for the problem.

$$F = \min \left\{ \alpha \int_0^t e(t)^2 dt + \beta |\overset{\text{overshoot}}{e}| \right\}$$

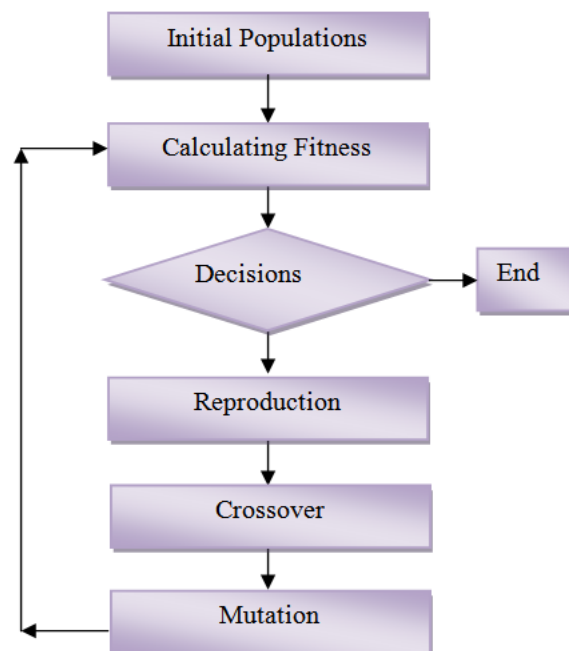


Fig. 1: illustrates the block structure of the PID controller optimizing process with GA.

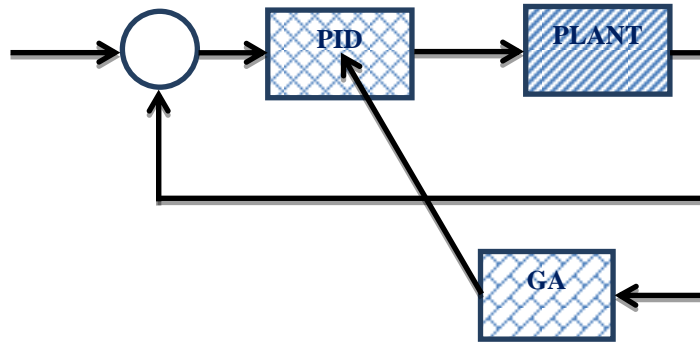


Fig. 2: Tuning process of the FOPID controller parameters with GA.

1. *AVR System Modeling:*

The task of an AVR system is to hold the terminal voltage magnitude of a synchronous generator at a specified level. Thus, the stability of the AVR system would seriously affect the security of the power system. A simpler AVR system contains five basic components such as amplifier, exciter, generator, sensor and comparator. The real model of such a system is depicted in Fig. 2. A unit step response of this system without control has some oscillations which reduce the performance of the regulation. Thus, a control technique must be applied to the AVR system. For this reason, the PID block is connected to amplifier seriously. The A small signal model of this system including PID controller which is constituted through the transfer functions of these components is depicted in Fig. 3, and the limits of the parameters used in these transfer functions are presented in Table 1(Z.L. Gaing,2004).

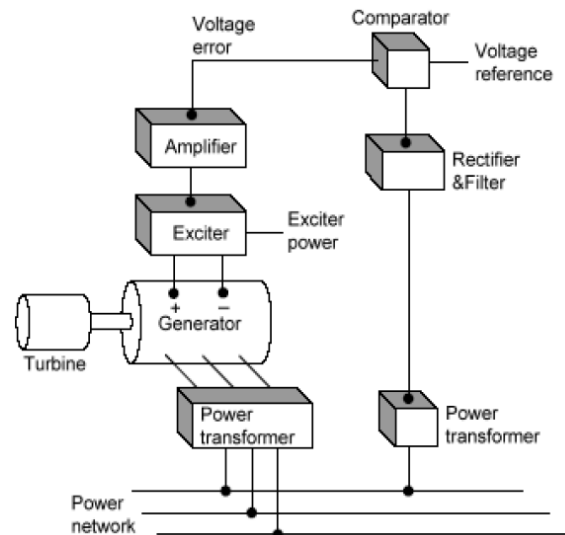


Fig. 3: A real model of AVR system(J. Holland1967).

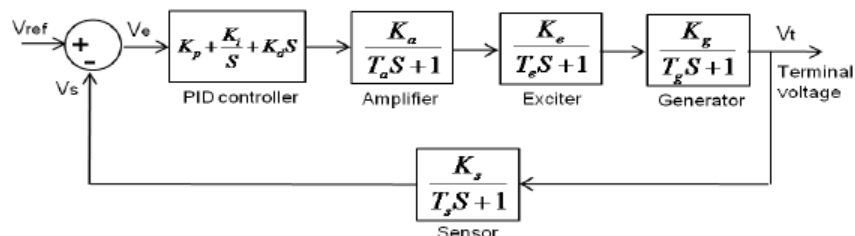


Fig. 4: Block diagram of AVR system.

1. *Simulation:*

We want to design a controller for the AVR system the fitness function for the system are chosen as follows.

$$F = \min\{(1 - e^{-\beta})(M_p + E_{ss}) + (e^{-\beta})(T_s + T_r)\}$$

Table 1: Parameters of AVR model with transfer function and parameter limits.

	Transfer function	Parameters limits
PID controller	$k_p + \frac{k_i}{s} + k_d \frac{N}{1 + \frac{N}{s}}$	$N = 100; 0 \leq k_p \leq 3$ $0 \leq k_i \leq 1; 0 \leq k_d \leq 1$
Amplifier	$TF_{amplifier} = \frac{K_a}{1 + \tau_a s}$	$10 \leq K_a \leq 40; 0.02 \leq \tau_a \leq 0.1$
Exciter	$TF_{exciter} = \frac{K_e}{1 + \tau_e s}$	$1 \leq K_e \leq 10; 0.4 \leq \tau_e \leq 1$
Generator	$TF_{generator} = \frac{K_g}{1 + \tau_g s}$	$0.7 \leq K_g \leq 1; 1 \leq \tau_g \leq 2$
Sensor	$TF_{sensor} = \frac{K_s}{1 + \tau_s s}$	$K_s = 1; 0.001 \leq \tau_s \leq 0.06$

The fitness is to reduce errors and overshoot. α And β is the weighted standard error and overshoot

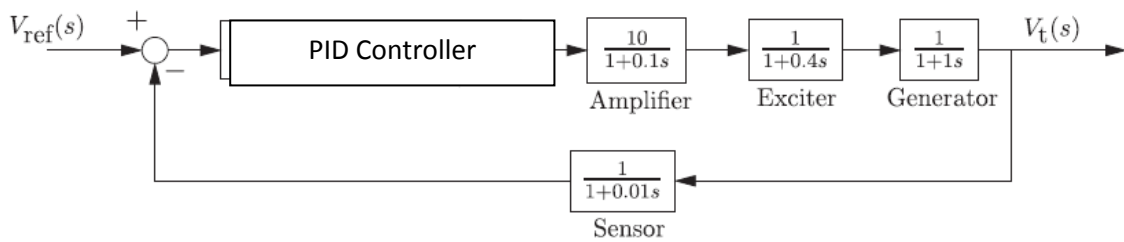


Fig. 5: Block diagram of AVR system.

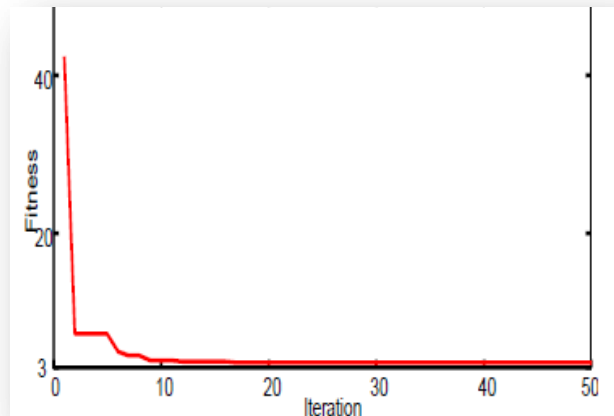


Fig. 6: Fitness convergence in GA method.

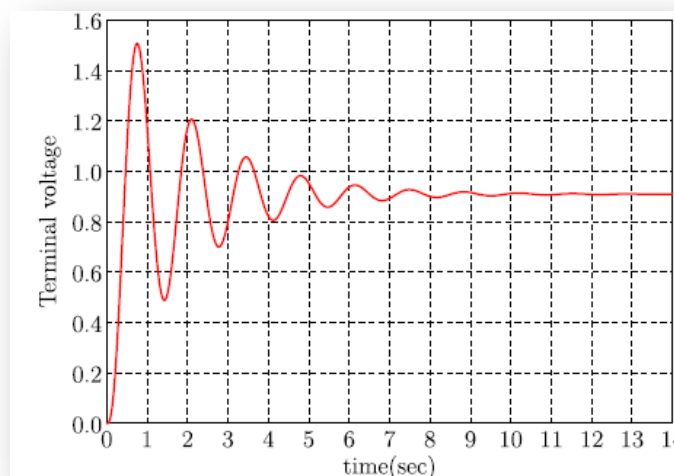


Fig. 7: Terminal voltage step response of AVR without controller.

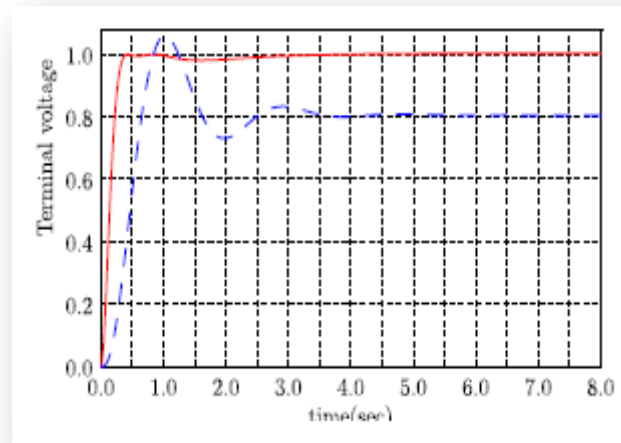


Fig. 8: Terminal voltage step response of AVR system controlled by GA-PID and ZN-PID controller $\beta = 1$

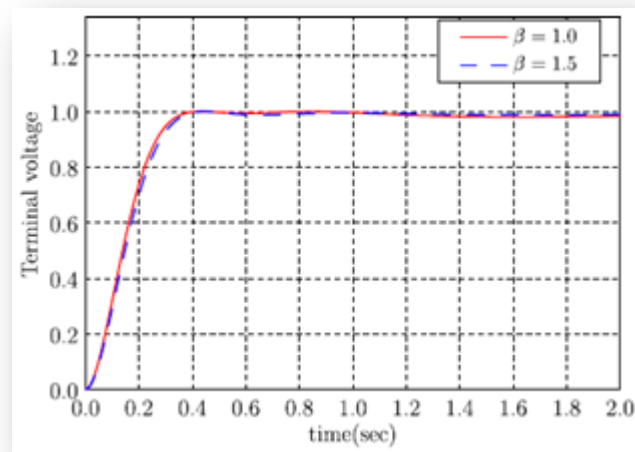


Fig. 9: Terminal voltage step response of AVR system controlled by GS-PID controller.

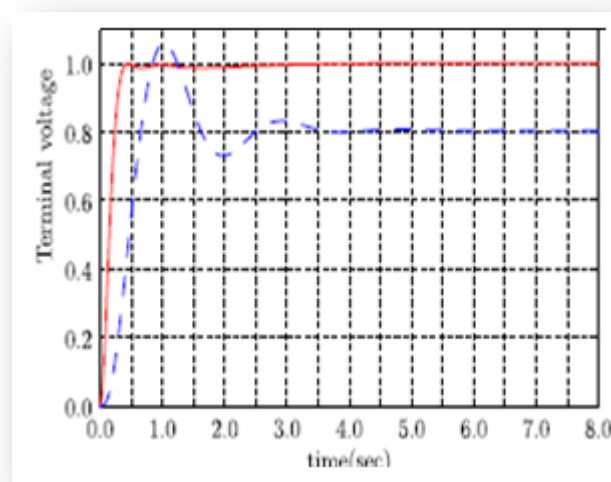


Fig. 10: Terminal voltage step response of AVR system controlled by GA-PID and ZN-PID controller $\beta = 1.5$

Conclusions:

This paper presents a novel and effective optimization algorithm to PID control design of AVR system using the GA algorithm in order to improve electromechanical oscillations in a power system. The main feature of GA is that it converges in the limit to a globally optimal solution with probability one under mild conditions. The GA with the new time domain performance criterion into a GA-PID controller. The problem of optimal tuning of PID gains is formulated as an objective optimization problem for a wide range of uncertain plant parameter changes. The results showed that the pro-posed approach is efficient to tune PID controller for AVR system.

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