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A Genetic Algorithm for Optimum Design of PID Controller in Load Frequency Control

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***Abstract*—**In this paper, determining the optimal proportional-integral-derivative (PID) controller gains of an single-area load frequency control (LFC) system using genetic algorithm (GA) is presented. The LFC is notoriously difficult to control optimally using conventionally tuning a PID controller because the system parameters are constantly changing. It is for this reason the GA as tuning strategy was applied. The simulation has been conducted in MATLAB Simulink package for single area power system. the simulation results shows the effectiveness performance of under various disturbance.

***Keywords*—**Load Frequency Control (LFC), PID controller and Genetic Algorithm (GA).

I. Introduction

MAINTAINING power system frequency at constant value is very important for the health of the power generating equipment and the utilization equipment at the customer end. The job of automatic frequency regulation is achieved by governing systems of individual turbine-generators and Automatic Generation Control (AGC) or Load frequency control (LFC) system of the power system [1].

The modern power systems with industrial and commercial loads need to operate at constant frequency with reliable power. Load Frequency Control (LFC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. The main goal of the LFC is to maintain zero steady state errors for frequency deviation and good tracking load demands in a multi-area restructured power system [2].

In this study, a single area power system is chosen and load frequency control of this system is made by a proportional integral derivative controller (PID) tuned by Genetic Algorithm (GA). Basically, single area power system consists of a governor, a turbine, and a generator with feedback of regulation constant. System also includes step load change input to the generator.

This work mainly, related with the controller unit of a single area power system.

A lot of studies have been made in the past about the load frequency control. In the literature, some control strategies have been suggested based on the conventional linear control theory [3]. Gain scheduling is a controller design technique used for non-linear systems. Therefore, a gain scheduling controller can be used for this purpose. In this method, since parameter estimation is not required, control parameters can be changed very quickly. In addition, gain scheduling application is easier than both automatic tuning and adaptation of controller parameters methods [4]. However, the transient response for this controller can be unstable because of abruptness in system parameters. Besides, it cannot be obtained accurate linear time variant models at variable operating points [4].

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II. Linearizing Model of an LFC System

The model of Generator, Load, prime mover and governor is obtained by transfer f unction method and combined to form a complete block diagram of an isolated power.

A. Generator Model

Applying swing equation of a synchronous machine to small perturbation, we have:

$$\frac{2H}{\omega_s}\frac{d^2\Delta\delta}{dt^2} = \Delta P_m - \Delta P_e \qquad (1)$$

or in terms of small deviation in speed:

$$\frac{d\Delta\frac{\omega}{\omega_s}}{dt} = \frac{1}{2H}(\Delta P_m - \Delta P_e) \qquad (2)$$

where

$\Delta P_m - \Delta P_e$= increment in power input to the generator.

H = Inertia constant

ΔP_m= mechanical power output or in terms of small deviation in speed with speed expressed in per unit, without explicit per unit notation, we have:

$$\frac{d\Delta\omega}{dt} = \frac{1}{2H}(\Delta P_m - \Delta P_e) \qquad (3)$$

Taking Laplace of transform of (3), we obtain:

$$\Delta\,\Omega\,(s) = \frac{1}{2Hs}[\Delta P_m(s) - \Delta P_e(s)] \qquad (4)$$

The generator block diagram in Fig. 1 is obtained from the (4).

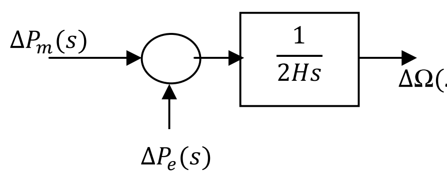

Fig. 1 Generator block diagram

B. Load Model

The load model on a power system consists of variety of electrical devices. Loads, such as lighting and heating loads, the electrical power is independent of frequency. Motor loads are sensitive to changes in frequency. The speed-load characteristic of a composite load is approximated by:

$$\Delta P_E = \Delta P_L + D\Delta\Omega \qquad (5)$$

where ΔP_L is the non-frequency sensitive load change, and $D\Delta\omega$ is the frequency sensitive load change, D is expressed as percent change in load divided by percent change in frequency. The load model and the generator model is combined as shown in Fig. 2.

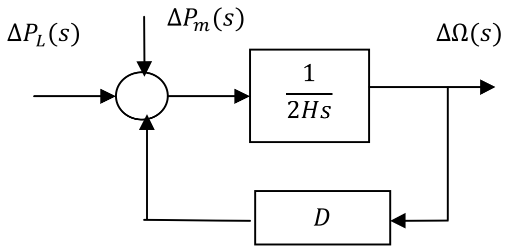

Fig. 2 Generator ad load diagram

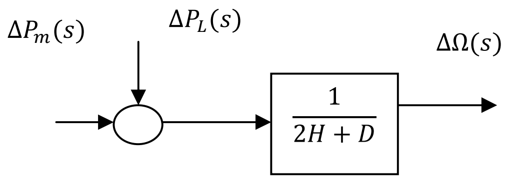

Fig. 3 Generator and load diagram

C. Prime Mover Model

The model for the turbine relates changes in mechanical power output ΔP_m to changes in steam valve position. The simplest prime mover model for the non-reheat steam turbine can be approximated with a single time constant, resulting in the transfer function under (6).

$$G_T(s) = \frac{\Delta P_M(s)}{\Delta P_V(s)} = \frac{1}{1+\tau_T s} \qquad (6)$$

The block diagram of a steam turbine in Fig. 4 is obtained from (6).

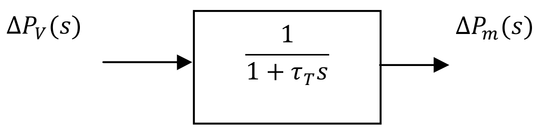

Fig. 4 Block diagram of simple steam turbine

D. Governor Model

When the generator electrical load is suddenly increased, the electrical power exceeds the mechanical power input. This power deficiency is supplied by the kinetic energy stored in the rotating system. The reduction in kinetic energy causes the turbine speed and consequently, the generator frequency to fall. The change in speed is sensed by the turbine governor, which acts to adjust the turbine input valve to change the mechanical power output to bring the speed to a new steady state. The earliest governors were the Watt governors which sense the speed by means of rotating fly balls and provide mechanical motion in response to speed changes. However, most modern governors use electronic means to sense speed changes.

E. Speed Changer

The speed changer consists of a servomotor which can be operated manually or automatically for scheduling load at nominal frequency. By adjusting this set point, a desired load dispatch can be scheduled at nominal frequency. For stable operation, the governors are designed to permit the speed to drop as the load is increased. The speed governor mechanism acts as a comparator whose output is ΔP_g the difference between the reference set power and the power $\frac{1}{R}\Delta\omega$

$$\Delta P_G = \Delta P_{REF} - \frac{1}{R}\Delta\Omega \qquad (7)$$

or in s-domain

$$\Delta P_g(s) = \Delta P_{ref}(s) - \frac{1}{R}\Delta\Omega(s) \qquad (8)$$

The command ΔP_g is transformed through the hydraulic amplifier to the steam valve position command ΔP_V. Assuming a linear relationship and considering a simple time constant τ_g, s-domain relation is

$$\Delta P_V(s) = \frac{1}{1+\tau_g s}\Delta P_g(s) \qquad (9)$$

Equations (8) and (9) are represented as speed governing system block diagram in Fig. 5.

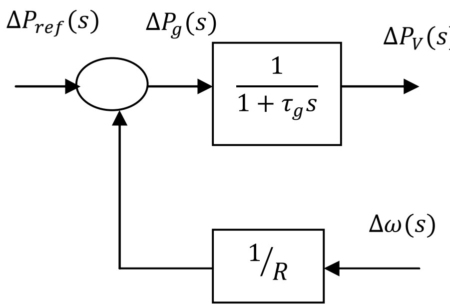

Fig. 5 Speed governor system for steam turbine

Complete block diagram of the load frequency control of an isolated power station shown in Fig. 6.

Load frequency control with PID controller is shown in Fig. 7.

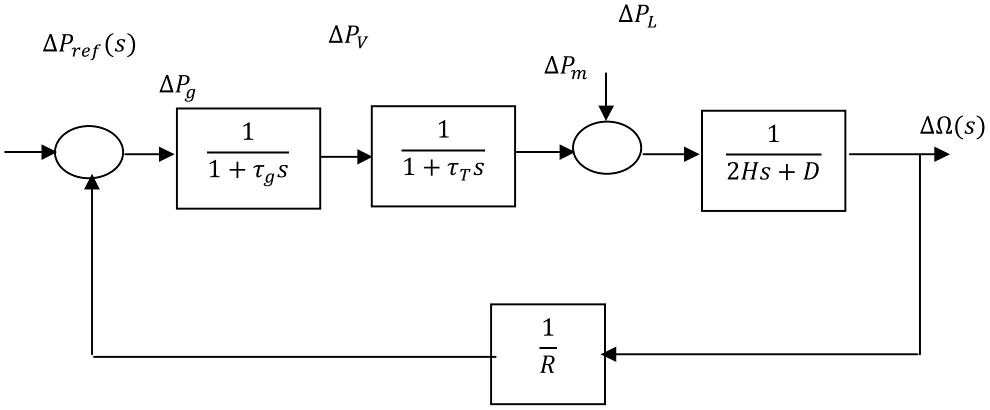

Fig. 6 LFC of an isolated power system

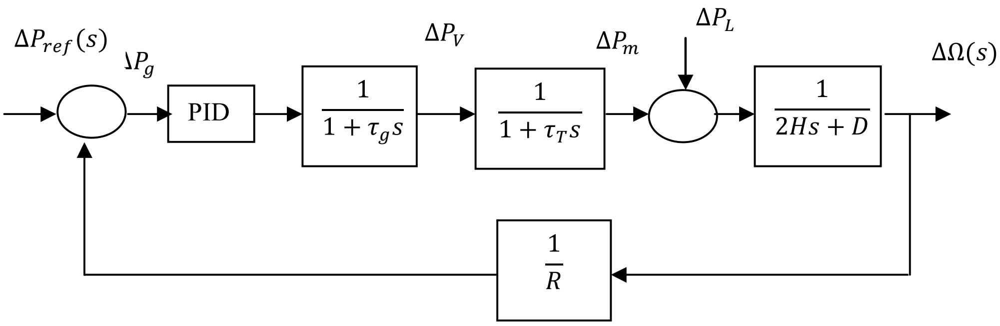

Fig. 7 LFC with PID controller

III. AGC IN SINGLE AREA POWER SYSTEM

With primary LFC control loop, a change in the system load will result in a steady state frequency deviation. In order to reduce the frequency deviation to zero (to eliminate steady-state error), we must provide integral action.

IV. PID CONTROLLER AND SINGLE AREA SYSTEM

PID controller [5] are being extensively used by industries today owing to their simplicity. Its main focus here is elimination of steady state error as well as an improvement in the dynamic response.

The derivative controller adds a finite zero to the open loop plant transfer function and improves the transient response. The integral controller adds a pole at the origin, thus increasing system type by one and reducing the steady state error due to a step function to zero. The PID controller transfer function is:

$$C(s) = K_p + \frac{K_i}{s} + K_d s. \tag{10}$$

In this paper the performance of PID controller designed using the integral of squared-error *(ISE)*, the *ISE* performance criterion formulas as follow:

$$ISE = \int_0^{\infty} e^2(t)dt \tag{11}$$

A set of good controller parameters K_p, K_i, and K_d can yield a good step response.

Incorporating the LFC with PID controller the result will be in Fig. 7.

V. GENETIC ALGORITHM

Genetic algorithms are stochastic global search method that mimics the process of natural evolution [6]. The genetic algorithm starts with no knowledge of the correct solution and depends entirely on responses from its environment and evolution operators (i.e reproduction, crossover and mutation) to arrive at the best solution. A genetic algorithm is typically initialized with a random population consists of between 20-100 individuals, this population is usually represented by real-values number or a binary string called chromosome.

A. Genetic Algorithm Process

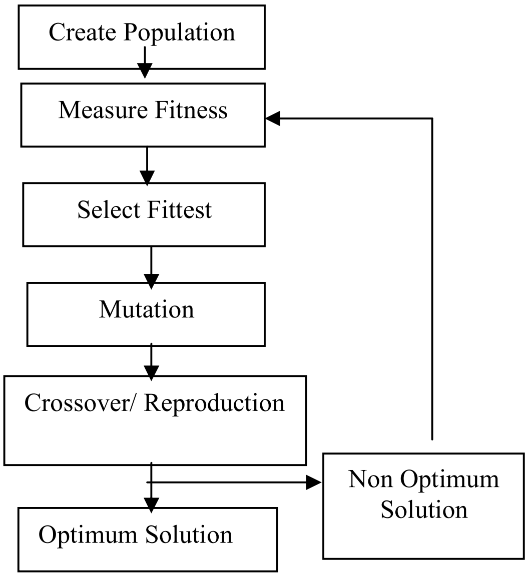

Fig. 8 Graphical Illustration the Genetic Algorithm Outline

The steps involved in creating and implementing a genetic algorithm are as follows:

- Generate an initial random population of individuals for a fixed size.
- Evaluate their fitness.
- Select the fittest members of the population.
- Reproduce using a probabilistic method.
- Implement crossover operation on the reproduced chromosome.
- Execute mutation operation with low probability.
- Repeat step 2 until a predefined convergence criterion is met.

VI. Evaluation of PID Gains

The genetic algorithm will now be used to evaluate the optimum gains of PID controller.

The population of the genetic algorithm was set to a value of (80) with variable bounds of each of three gains of the controller set to -100 and +100. The termination options for the genetic algorithm was set to the maximum generation termination value of (100) and the number of mutations to take place throughout the course of the GA was set to (8).

Evaluated PID gains values of:

$$K_P = 3,\ K_I = 1,\ K_D = 0.6$$

VII. Simulation Study

The simulation has been conducted in MATLAB Simulink package for single area power system with PID controller as in Fig. 7. The step function is applied at t= 1 second. Form the simulation result the one noted that there is no steady state error, the settling time is 7 second and the rise time is only 1 second which is suitable due to the large time constant of the governor and steam turbine.

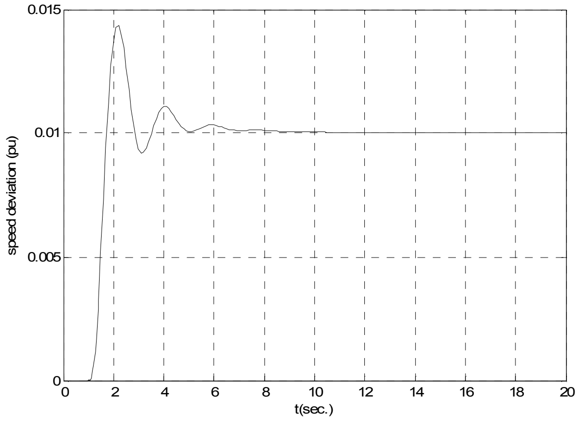

Fig. 9 Speed deviation in single area power system

VIII. Conclusion

In this study, a genetic algorithm tuning proportional integral derivative controller has been investigated for automatic load frequency control of single area power systems.

The Simulink package for single area power system with PID controller is developed in MATLAB as in Fig. 7. The simulation result shown that the proportional-integral-derivative tuning its parameters via genetic algorithm has small rise time, less settling time and no steady state error. Two area power system operation will be investigated in next time.

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