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Modified Genetic Algorithm Based Load Frequency Controller for Interconnected Power Systems

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Abstract: Power engineers have the responsibility to deliver economically, adequate and quality power to the consumers. In order to achieve this, the power system must be maintained at the desired operating level by suitable modern control strategies. The controlling of power system is becoming increasingly more complex due to large interconnections. The load frequency control is very important in power system operation and control for supplying sufficient and reliable electric power with good quality. This study deals with the application of real coded genetic algorithm for optimizing the gain of a proportional integral controller for load frequency control of interconnected power systems. Non-linearities such as Governor Dead Band (GDB) and Generation Rate Constraints (GRC) for a two-area reheat thermal power system have been included. Floating point representation has been used, since it is more consistent, more precise and leads to faster convergence. The simulation results confirm the designed control performance of the proposed controller.

Key words: Load frequency control, controller design, genetic algorithm

INTRODUCTION

Power engineers have the responsibility to deliver economically, adequate and quality power to consumers. In order to achieve this, the power system must be maintained at the desired operating level by suitable modern control strategies. The control of power systems is becoming increasingly more complex due to large interconnections. In an interconnected network, a disturbance in one line leads to effects on the neighbouring systems change in tie-line power and frequency causing serious problem of Load Frequency Control. Load Frequency Control (LFC) is a mechanism to maintain or restore the frequency and tie-line power flow among the interconnected power systems within the specified limit.

LFC is a very important item in power system operation and control for supplying sufficient and reliable electric power with good quality. There has been continuing interest in designing load frequency controller with better performance during past 30 years. Many control strategy for LFC have been proposed, since the 1970s (Chidambaram and Velusamy, 2005; Bevrani *et al*., 2004). These approaches offer a reasonably good performance for limited range of operating condition. Ensuring such desirable performance for a wide range of operation is rather difficult due to non-linearity of the system. In addition, although these techniques offer a tangible improvement, they are all more complicated than the popular PI approach.

Genetic Algorithms (GA) are exploratory search and optimization procedures that were derived on the principle of natural evaluation and population genetics. The basic concept of GA was developed by Holland and his students (Masiala *et al*., 2004; Michalewicz, 1996). It has been shown that GA can control a dynamic system without any prior knowledge about the system. The binary coding or bit string-coding (Michalewicz, 1996) is the most classic method used by GA researchers because of its simplicity and traceability. The conventional GA operation and theory are also developed on the basis of this fundamental structure. Hence, this representation is adopted in many applications.

Recently, a direct manipulation of real value chromosomes raised considerable interest. This representation was introduced especially to deal with real parameter problems. It is indicated that the floating-point representation would be faster in computation and more consistent form the basis of run-to-run. At the same time, its performance can be enhanced by special operation to achieve high accuracy (Baskar *et al*., 2002). In this study, Genetic Algorithm is used for optimising the gains of a PI

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controller of a two area reheat thermal power system. Real coded GA is employed in this study for the design of an efficient load frequency controller (Dulpichet and Ali, 2003; Chowdhury *et al*., 1999).

MODELING OF TWO AREA REHEAT THERMAL POWER SYSTEM

Transfer function model: The transfer function model of a two-area thermal reheat power system using simplified model are considered. A two-area system may be represented for the load frequency control in terms of its components like governor system, turbine, generator, load and tie line between two-area (Bevrani *et al*., 2004). It is convenient to obtain the dynamic model in state variable form from the transfer function model.

State space model: The standard state space modelling employed is described in the matrix form as:

$$\dot{X} = Ax + Bu + Cd \tag{1}$$

Where, the system state vector X consists of nine variables as:

$$[x] = [\int ACE_1 dt \int ACE_2 dt\ \Delta F_1\ \Delta P_{g1}\ \Delta X_{e1}\ \Delta P_{tie1}\ \Delta F_2\ \Delta P_{g2}\ \Delta X_{e2}]^T$$

$$\text{System control input vector is } [u] = \begin{vmatrix} u_1 \\ u_2 \end{vmatrix} = \begin{vmatrix} \Delta P_{c1} \\ \Delta P_{c2} \end{vmatrix}$$

$$\text{System disturbance input vector is } [d] = \begin{vmatrix} d_1 \\ d_2 \end{vmatrix} = \begin{vmatrix} \Delta P_{d1} \\ \Delta P_{d2} \end{vmatrix}$$

A, B and C are system state matrix, distribution matrix and disturbance distribution matrix of appropriate dimensions. These matrix and vectors are obtained using the nominal parameters of the system. A step load of 1% has been considered as a disturbance in the two-area reheat thermal power system.

REAL CODED GENETIC ALGORITHM

Genetic Algorithms are search procedures whose mechanics are based on those of natural genetics. Genetic Algorithms (GAs) are simple, derivative free, effective and quite robust in solving the optimization problems inspired by the laws of natural selection and genetics (Masiala *et al*., 2004). GAs can provide near global solution and can also, handle the control variable effectively. GAs search from a population of points, not a single point. This population can move over hills and across valleys. GAs can therefore discover a globally optimal point. Because the computation is independent of the others, GAs have an inherent parallel computation ability.

Genetic algorithm consists of a population of bits (reproduction) transformed by three genetic operators such as selection, crossover and mutation (Masiala *et al*., 2004). Each chromosome represents a possible solution for the problem being optimized and each bit represents a value for some variable of the problem. The first population is generated at random and each new generation is created by the selection or reproduction operator and altered by cross over and mutation for better solution.

For real valued numerical optimization problems, floating point representations outperform binary representation because they are more consistent, more precise and lead to faster convergence (Baskar *et al*., 2002; Michalewicz, 1996). For most applications of genetic algorithms to constrained optimization problems, the real coding technique is used to represent a solution to a given problem. Hence, real coded genetic algorithm is considered in this study.

Parents are initialised by selecting a random number in the range (0.0-1.0) for each element of a chromosome. Each chromosome, P_i, i = 1, 2....n_p in the population is converted into a form appropriate for evaluation (actual problem variable, b_a) and then is assigned a fitness value according to the objective function. More over, the lower and upper bound inequality condition has been embedded in the coding itself by the elements of chromosomes in the range (0.0,1.0) using following encoding scheme.

$$b_a = b_{min} + (b_{max} - b_{min}) \times b_i$$

Where:

b_{max} and b_{min} = Upper and lower bound on problem variables.

b_a = The actual solution variable.

b_i = Normalized solution variable.

The evaluation function evaluates the fitness of chromosome as a solution to the optimization problem. It is also, referred to as the fitness function and is maximized during the search for the global optimum solution.

The binary representation commonly used in GA has some weakness when applied to multi dimensional high precision numerical problem. Adopting the floating-point (real coded) representation with special genetic operator for parameter optimization problem is justified for many reasons. A floating-point representation is conceptually nearest to the problem space and facilitates the efficient implementation of operations. In addition the floating-point representation is generally more precise than the binary representation. Moreover, the floating point representation can represent reasonably large domains or variables.

Real coded GA is implemented as follows (Baskar *et al*., 2002):

Step 1: A population of np trail solutions is initialized. The solution is taken as a real valued variable with the dimensions corresponding to the number of variables. The initial components are selected in accordance with a uniform distribution range.

Step 2: The fitness score for each solution variable is evaluated, after converting each solution variable into corresponding problem variables using upper and lower bounds.

Step 3: Roulette wheel based selection method is used to produce np offspring from parents.

Step 4: Crossover and mutation operators are applied to offspring to generate next generation parents.

Step 5: The algorithm proceeds to step 2, unless the best solution does not change for a pre- specified interval of generations.

APPLICATION OF REAL-CODED GA TO LFC FOR INTERCONNECTED POWER SYSTEMS

This section utilises the application of real-coded GA for optimizing the gains of a proportional plus integral controller for a two-area reheat thermal power system. In this study, the load is taken as the reference input and the ACE is the output that is to be controlled (Juang and Lu, 2004). A proportional Plus Integral (PI) controller is placed in the feedback path from the frequency to the gate input. The main objective is to minimize the Mean Square Error (MSE) of the Area Control Error (ACE) due to step type load disturbance. The objective function of the load frequency controller is given by,

$$J = \int_0^t ACE_i^2\, dt \qquad (2)$$

Where:

$$i = 1, 2$$

$$ACE_i = \beta \Delta F_i + \Delta p_{tiei}$$

β is the biasing factor.

The real-coded genetic algorithm is used to minimize the Area Control Error (ACE) of the two-area reheat thermal interconnected power system. The fitness value should be calculated for the purpose of minimizing the Area Control Error (ACE). The fitness function is given by:

$$\text{Fitness}(F) = \frac{1}{1+J} \qquad (3)$$

For a particular setting of the PI controller gains K_p and Ki, if the objective function is less value, then the fitness is large value and vice versa (Baskar *et al*., 2002). The real coded GA manipulates coding of the parameter in the form of continuous variable. Each parameter set K_p and K_i should be used to calculate the objective function. At different values of continuous variable, fitness is to be calculated by using the real coded GA. The goal of real coded GA is to manipulate a population of variables such that the average fitness of the population increases.

The real coded GA is to calculate the objective function using each parameter set. These objective function values are then mapped into a fitness value for each variable set using the Eq. (3) The genetic operators are applied to offspring (present parents) to generate the next generation parents. The above procedure is repeated from all generation until the population is converged and produce the optimal value of K_p and K_i. This optimal value K_p and K_i indicates the best fitness value among all generation.

RESULTS

The real coded GA parameters for the simulation of Load Frequency Control (LFC) of a two-area reheat thermal interconnected power system are given in the Table 1.

The optimal parameter sets for the conventional PI controller and real coded GA based PI controllers are presented in Table 2.

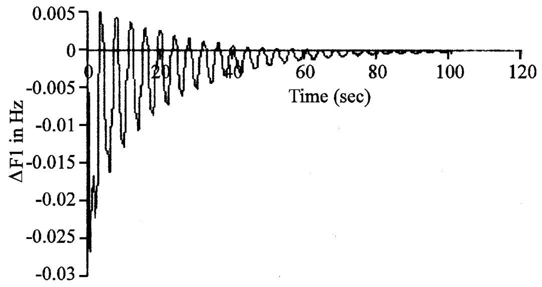

Fig. 1: Frequency deviation in area 1 of a two area thermal reheat power system without non-linearitits for a step load disturbance

Table 1: Real coded GA parameters

Number of real coded variables	2.000
Total number of generation	30.000
Population size	10.000
Cross over probability	0.400
Mutation probability	0.001

Table 2: Optimal parameter sets

Controller	Gains	K_p	K_i
Without non-linearities	Conventional	0.760	0.062
	GA based	0.746	0.061
With GDB	Conventional	0.870	0.069
	GA based	0.847	0.070
With GRC	Conventional	1.060	0.077
	GA based	1.055	0.076

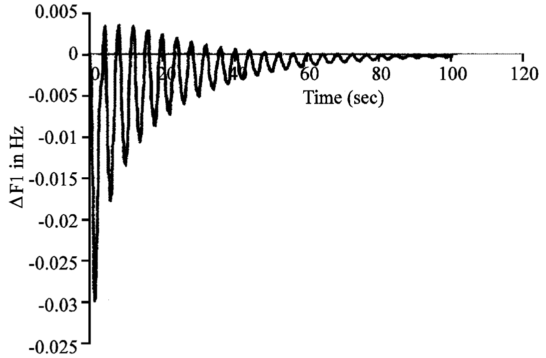

Fig. 2: Frequency deviation in area 2 of a two area thermal reheat power system without non-linearitits for a step load disturbance

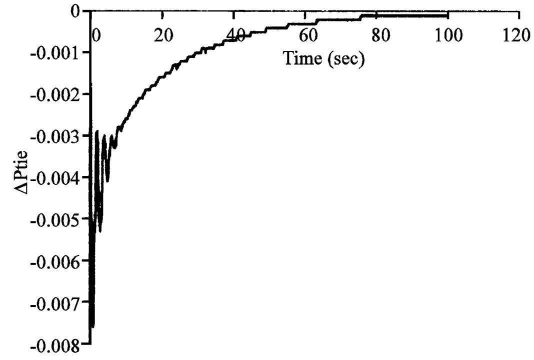

Fig. 3: Tie lin power flow deviation of a two area thermal reheat power system without non-linearitits for a step load disturbance

From the Table 2, it is seen that the optimum K_p and K_i values obtained using real coded GA are almost identical to those obtained for conventional PI controller.

Figure 1-3 show the closed loop responses of the two-area thermal reheat power system without non-linearity for the gains obtained in Table 2. Figure 4-6 show the closed loop responses of the two-area thermal reheat

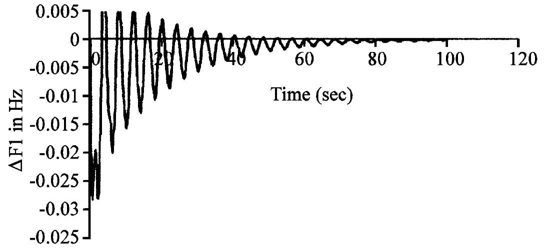

Fig. 4: Frequency deviation in area 1 of a two area thermal reheat power system with GDB for a step load disturbance

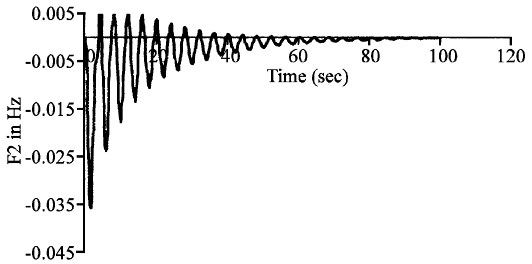

Fig. 5: Frequency deviation in area 2 of a two area thermal reheat power system with GDB for a step load disturbance

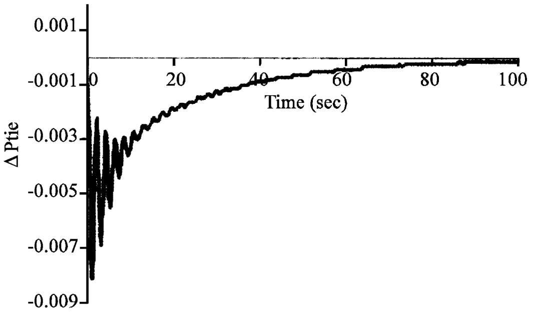

Fig. 6: Tie line power flow deviation of two area thermal reheat power system with GDB for a step load disturbance

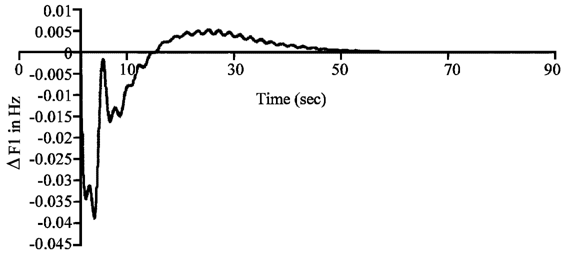

Fig. 7: Frequency deviation in area 1 of a two area thermal reheat power system with GRC for a step load disturbance

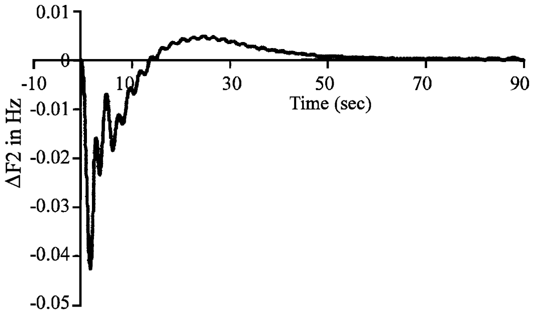

Fig. 8: Frequency deviation in area 2 of a two area thermal reheat power system with GRC for a step load disturbance

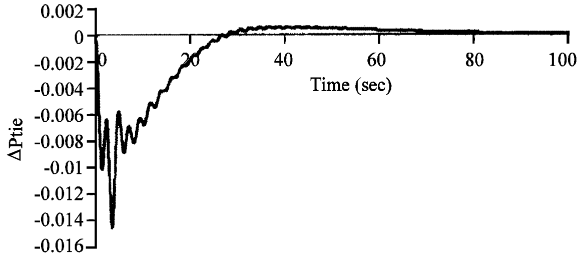

Fig. 9: Tie line power flow deviation of a two area thermal reheat power system with GRC for a step load disturbance

power system with GDB. Figure 7-9 show the closed loop responses of the two-area thermal reheat power system with GRC.

CONCLUSION

Application of Real-coded GA for optimising the gains of a proportional plus integral controller for a two-area thermal reheat power system has been discussed in this study. Non-linearities such as GDB and GRC have been included in the study. Simulation results show that the gains obtained using real coded GA are almost identical to those obtained for a conventional PI controller. This investigation can be extended for optimising the gains of a fuzzy gain controller or a neuro-controller in future.

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Appendix 1: Two area reheat thermal power system

β_1	=	β_2	=	0.425 p.u .M..W/Hz.
T_{t1}	=	T_{t2}	=	0.3 sec
T_{g1}	=	T_{g2}	=	0.08 sec
K_{ps1}	=	K_{ps2}	=	120Hz/p.u. MW
$2\pi T_{12}$	=	0.545		
T_{ps1}	=	T_{ps2}	=	20 sec
R_1	=	R_2	=	2.4 Hz/p.u MW.
T_{r1}	=	T_{r2}	=	10 sec
K_{r1}	=	K_{r2}	=	0.5 sec
N_1	=	0.8		
N_2	=	-0.06		

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