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Automatic Generation Control of Complex Power Systems Using Genetic Algorithm: A case Study

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Abstract

In this paper the automatic generation control (AGC) of a hydro thermal power system is considered. The load frequency control is obtained using conventional integral controller. The genetic algorithm is used for the optimization of integral gain Ki of the controller. The state space model of a hydro thermal power system had been considered for the analysis. The effects of nonlinearities were eliminated. The comparison of simulation results reveals that GA optimized controller will give improved result than the conventional controller. Kerala power system is taken as a case study in this paper.

1. Introduction

The main objective of power system operation and control is to maintain continuous supply of power with an acceptable quality, to all the consumers in the system. The system will be in equilibrium, when there is a balance between the power demand and the power generated. In an electric power system, consumers require power at rated frequency and voltage. To maintain these parameters within the prescribed limits, controls are required on the system.

There are two basic control mechanisms used to achieve acceptable voltage profile and acceptable frequency value (real power balance). The control for acceptable frequency values is called the automatic load frequency control (ALFC) or automatic generation control (AGC).

Automatic generation control (AGC) plays a very important role in power system as its main role is to maintain the system frequency and tie line flow at their scheduled values during normal period and also when the system is subjected to small step load perturbations. Many investigations in the field of automatic generation control of interconnected power system have been reported over the past few decades.

Generation in large interconnected power system comprises of thermal, hydro, nuclear and gas power generation.[3] Nuclear units are usually kept at base load close to their maximum output with no participation in system automatic generation control **(AGC)** due to their high efficiency**.** Gas power generation is ideal for varying load demand. However, these plants form a very small percentage of total system generation. So such plants do not play very significant role in AGC of a large power system, since. Gas plants are used for peak demands only. Thus the natural choice for AGC falls on either thermal or hydro units. Most of earlier works in the area of AGC is concentrated to interconnected thermal systems and relatively lesser attention has been devoted to the AGC of interconnected hydro-thermal system involving thermal and hydro subsystem of widely different characteristics.

The conventional automatic generation controllers (AGC) are usually designed for working at specific operating points, and they are not more efficient for modern power systems, considering increasing size, emerging renewable energy sources, changing structure, and uncertainties. Most of the conventional AGC synthesis methodologies provide model based controllers that are difficult to use for large-scale power systems with nonlinearities and uncertain parameters. Most AGC are primarily composed of integral controller. The integrator gain is set to a level that compromise between fast transient recovery and low overshoot in the dynamic response of overall system. The integral term adds a pole at origin resulting in increasing the system type and therefore reducing the steady state error.

The drawbacks of conventional integral controllers can be summarized as:

- They are slow in action.
- They do not take into account the inherent nonlinearities of various power system components like governor dead band effects, use of reheat type of steam turbines in thermal systems, generation rate constraints (GRCs) etc.
- While the load varies continuously during the daily cycle, the operating point also changes accordingly. This is in fact the inherent characteristic of a power system.[2],[3]

For better results, it is expected that using intelligent AGC schemes in new environment to be more flexible than conventional ones, and is going to become an appealing approach. The AGC problem has been augmented with the valuable research contributions from past, like AGC regulator designs incorporating parameter variations/uncertainties, load characteristics, excitation control and parallel ac/dc transmission links. The micro processor-based regulator, self-tuning regulator, and adaptive regulator designs have been presented. The most recent advancement in the AGC is the application of artificial intelligence techniques such as neural networks, fuzzy logic, genetic algorithms [1] etc. to tackle the difficulties associated with the design of regulators with nonlinear models and insufficient knowledge about the system. Intelligent control techniques are of great help in implementation of AGC in power systems.

This paper presents a genetic algorithm based method for tuning the integral controller of hydro thermal AGC. Area control error (ACE) of AGC scheme has been used as fitness function to tune the controller parameters. The Kerala power system has been considered as a case study for proposed method.

The section II gives an idea about the genetic algorithm. Section III considers the system investigated for the simulation. The simulation results and discussion shows the effectiveness of the genetic algorithm tuning.

2. Genetic Algorithm

The genetic algorithm is a global search technique for solving optimization problems, which is essentially based on the theory of natural selection, the process that drives biological evolution. It was developed by John Holland in 1970. GA solves optimization problems by exploitation of random search. . When searching a large space GA may offer significant benefits over the conventional optimization techniques .They are (i) they work on encoding of control variables, rather than variables themselves, (ii) they search from one population of solution to another, rather than from individual to individual, (iii) they use only objective functions, not derivatives, hence they are derivative free optimization techniques and they do not rely on the detailed model of the system to be optimized.

Genetic algorithm repeatedly modifies a population of individual solutions. At each step algorithm selects individuals at random from the current population, to be the parents and uses them to produce the children for the next generation. The successive generation of population leads towards an optimum solution. GA performs searches through a given set of alternatives with respect to the given criteria of goodness. These criteria are required to be expressed in terms of an objective function .It is also referred as fitness function. Fitness is defined as a figure of merit, which is to be maximized or minimized. GA starts with randomly creating the initial population of binary strings called chromosomes. Each chromosome representing a possible solution to the optimization problem and is evaluated according to the fitness function.

GA performs three basic operations such as reproduction, cross over and mutation.

Reproduction creates new generation of chromosomes. There are many mating technique available to pick two parent chromosomes to produce child chromosomes .Selection methods may be Roulette wheel selection, Rank selection etc.

*Cross over and mutation*s are used to select the individual to be copied over to the next generation. The process of crossover enables the extraction of best genes from different individuals and recombination of them to produce superior children. Mutation puts to the diversity of population and increases the like hood that the algorithm generates individuals with better fitness values.

2.1. Algorithm

Steps involved determining the optimal parameters of the controller using genetic algorithm are given below.

1. Start : Create random population of N chromosomes
2. Fitness : Evaluate fitness f(x) of each chromosomes in the population
3. New population: New population is created using GA operators
   a. Selection : Based on f(x)
   b. Recombination : Cross-over chromosomes
   c. Mutation : Mutate chromosomes
   d. Acceptation : reject or accept new one
4. Replace : old with new population and the new generation
5. Test : Test for problem criterion
6. Loop: Continue step 2-5 until criterion is satisfied.

Then the old population is replaced by new population. The process is continued till the termination criterion is reached. In this paper the objective function is chosen as the area control error of AGC. By minimizing the fitness function we get the optimal parameters of the integral controller.

3. System Investigated

In two-area system, two single area systems are interconnected using the tie line [10] as shown in fig 3. Interconnection established increases the overall system reliability [11]. Even if some generating units in one area fail, the generating units in the other area can compensate to meet the load demand. It is quite important to analyze the steady-state frequency deviation, tie-flow deviation and generator outputs for an interconnected area after a load change occurs.

Here for the analysis, considered a hydrothermal power system. Each area consists of mechanical speed governing system, turbine, and power system (load system). The two areas are interconnected using tie line. The tie line time constant is represented as T_{12}.The values used for simulation are given in appendix. Figure 1 shows the model used for the simulation in Matlab.

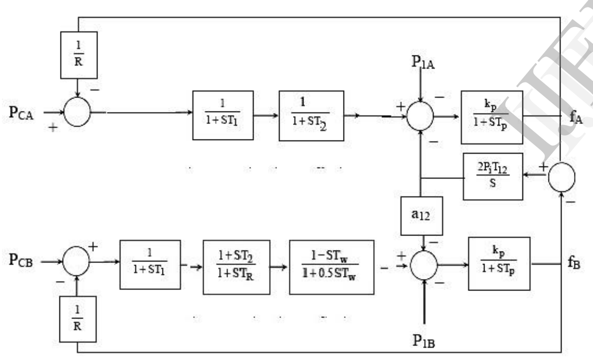

Figure 1.Simulation model of hydro thermal system

5. Case Study :Kerala Power System

The Kerala State Electricity Board (KSEB) is a public sector agency under the Government of Kerala, India that generates and distributes the electricity supply in the state. In this paper, the 220 KV Kerala power system is taken as a case study. There are 8 generating stations connected to 220 KV sub stations. Among them, there are 4 hydro electric projects,2 diesel power plants,1 wind plant and 1 thermal plant. In this paper, the 220 KV hydro and thermal power plants are used here for the analysis. For modeling of Kerala power system , we have to find out the load of Kerala power system Kp and Tp. For that we must find inertia constant ,H sys of each generating station

$$H_{sys}=H_{mach} *(G_{mach}/G_{system})$$

For Kerala power system,

H_{sys}=5.8389 sec
Tp=2H/Bf
Tp1=Tp(hydro)=25.7875 sec
Tp2=Tp(thermal)=3.40695sec
B=0.425

4. Results and Discussion

We present the simulation results of the proposed controllers for a hydro thermal system in this section. The AGC system investigated consists of thermal and hydro generating plants and the effects of nonlinearities are eliminated here. The state space model is used for the simulation in Matlab. The objective function for genetic algorithm is chosen as the ACE of each control area. Our aim is to reduce the area control error to zero so that the system frequency becomes constant within lesser settling time. The response for hydro thermal systems can be shown as in fig 2 and 3.

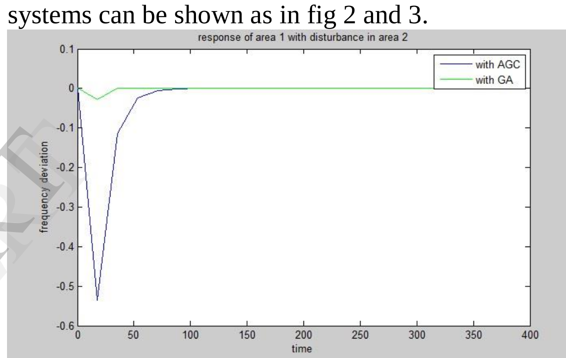

Figure 2. Frequency deviation of control area 2 in hydro thermal system

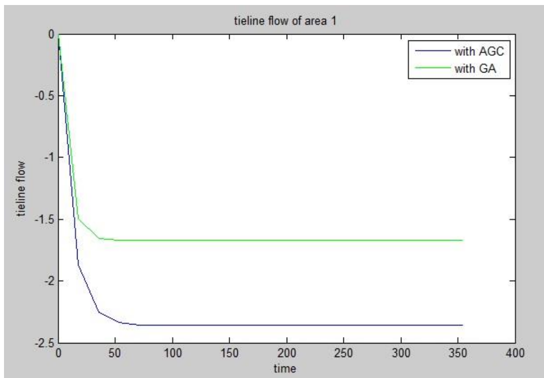

Figure.3.Tieline flow in area 2 with disturbance in area1

The simulation results shows that the GA tuned PI controller is better than the conventional PI controller. The GA optimized controller reduces the settling time and gives fast convergence than the conventional one. The simulation results for Kerala power systems are given below. Fig.4 gives the frequency deviation of control area 1 with disturbance of 1 pu in area 2 using GA tuned controller. Fig 5 gives the tie line flows in area 1.

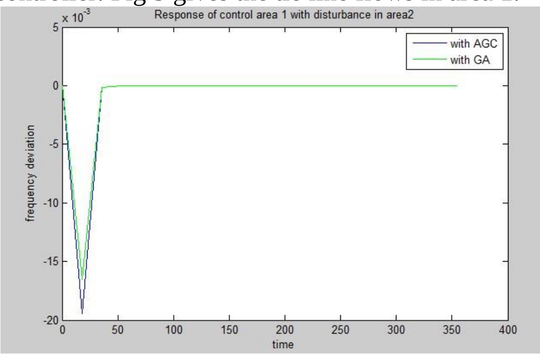

Figure 4. Frequency response of area 1 using GA tuned controller

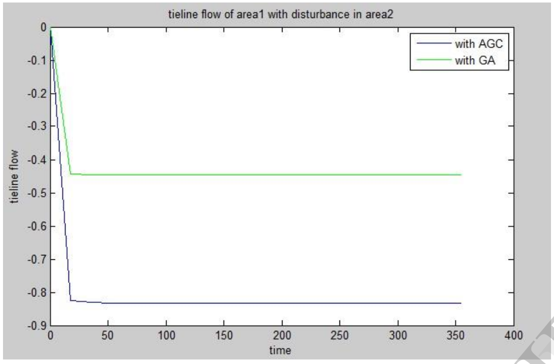

Figure 5. Tie line flow in area1 using GA

6. Conclusions

In this paper Automatic Generation Control is designed for a hydro thermal system. To improve the performance of conventional integral controllers, we tuned the integral gains using Genetic Algorithm and the simulation results shows the efficiencies of AI tuned controllers over the conventional one. Kerala power system is also considered as a case study.

Appendix

A. Thermal system

K_p= 120 Hz/pu MW, B = 0.425, R=2.40 Hz/pu MW, T_p= 24sec, T_1=0.08 sec, T_2= 0.3 sec

B. Hydro system

D=2,C=3,K_p=250Hz/pu MW , B=0.425, R=0.1Hz/pu MW, T_p=64 sec ,T_1=0.01,T_2=0.001, T_w=4.

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