AGC of an Interconnected Power System Before and After Deregulation

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***Abstract* - In this paper, the traditional AGC two-area system is modified to take into account the effect of bilateral contracts on the dynamics. The concept of DISCO participation matrix to simulate these bilateral contracts is introduced and reflected in the two-area block diagram.**

Key words: - Automatic generation control, bilateral contracts, deregulation, optimization, power system control, trajectory sensitivity.

I. INTRODUCTION

In this paper, we formulate the two area dynamic model following the ideas presented by Kumar [1], [2]. Specifically we focus on the dynamics, trajectory sensitivities and parameter optimization. The concept of a DISCO participation matrix is proposed which helps the visualization and implementation of the contracts. The information flow of the contracts is superimposed on the traditional AGC system and the simulations reveal some interesting patterns. The trajectory sensitivities are helpful in studying the effects of parameters as well as in optimization of the ACE parameters viz. tie line bias and frequency bias parameter. The traditional AGC is well discussed in the papers of Elgerd and Fosha [3], [4]. Research work in deregulated AGC is contained in [1], [2], [5], [6]. The paper is organized as follows. In Section II, we explain how the bilateral transactions are incorporated in the traditional AGC system leading to a new block diagram. Simulation results are presented in Section III. In Section IV, we discuss trajectory sensitivities and the optimization of and parameters using these sensitivities. Section V presents numerical results on optimization and a comparison of the responses using optimal and nominal values of the parameters.

II. RESTRUCTURED SYSTEM

The traditional power system industry has a vertically integrated utility structure. In the restructured or deregulated environment, vertically integrated utilities no longer exist. The utilities no longer own generation, transmission, and distribution; instead, there are three different entities, GENCOs, TRANSCOs and DISCOs. As there are several GENCOs and DISCOs in the deregulated structure, a DISCO has the freedom to have a contract with any GENCO for transaction of power. A DISCO may have a contract with a GENCO in another control area. Such transactions are called bilateral transactions. All the transactions have to be cleared through an impartial entity called an independent system operator. The ISO has to control a number of so-called “ancillary services,” one of which is AGC. In the restructured environment, GENCOs sell power to various DISCOs at competitive prices. Thus, DISCOs have the liberty to choose the GENCOs for contracts. They may or may not have contracts with the GENCOs in their own area. This makes various combinations of GENCO-DISCO contracts possible in practice. We introduce the concept of a DISCO participation matrix to make the visualization of contracts easier.DPM is a matrix with the number of rows equal to the number of GENCOs and the number of columns equal to the number of DISCOs in the system. Each entry in this matrix can be thought of as a fraction of a total load contracted by a DISCO toward a GENCO. Thus, the entry corresponds to the fraction of the total load power contracted by DISCO from a GENCO. The sum of all the entries in a column in this matrix is unity. DPM shows the participation of a DISCO in a contract with a GENCO; hence the name DISCO participation matrix.

III.AUTOMATIC GENERATION CONTROL

Modern power system consists of number of utilities interconnected together and power is exchanged between utilities over tie-lines by which they are connected. In order to achieve interconnected operation of a power system, an electric energy system must be maintained at a desired operating level characterized by nominal frequency, voltage profile and load flow configuration. This is achieved by close control of real and reactive powers generated through the controllable source of the system. Automatic generation control (AGC) plays a significant role in the power system by maintaining scheduled system frequency and tie-line flow during normal operating conditions and also during small perturbations. LFC system performance was evaluated with a nonlinear neural network controller using a generalized neural structure to yield better system dynamic performance than the individual neurons .Recently, a four-area interconnected power system model with reheat nonlinearity effect of the steam turbine and upper and lower constraints for generation rate nonlinearity of hydro turbine was considered for the investigation . It has been shown that the AGC problem can be viewed as a stochastic multistage decision-making problem or a Markov Chain control problem and have presented algorithms for designing AGC based on a reinforcement learning approach. The fuzzy logic control concept departs significantly from traditional control theory, which is essentially based on mathematical models of the controlled process. Instead of deriving a controller via modeling the controlled process quantitatively and mathematically, the fuzzy control methodology tries to establish the controller directly from domain experts or operators who are controlling the process manually and successfully. More recent contributions considering the problem of decomposition of multivariable systems for the purpose of distributed fuzzy control was reported by Gegov. The proposed decomposition method has reduced the number of interactive fuzzy relations among subsystems. The concept and development of AGC using ANN and fuzzy set theory to utilize the novel aspects of both in single hybrid AGC system design for power systems has also been mooted. These days, GA is the most popular and widely used algorithm of all the intelligent algorithms. Gases have been widely applied to solve complex nonlinear optimization problems in a number of engineering disciplines in general and in the area of AGC of power systems in particular.

IV.MODELLING OF SINGLE & TWO-AREA AGC POWER SYSTEM

To understand the automatic generation control problem, let us consider a single turbo-generator system supplying an isolated load.

Fig. 1 shows schematically the speed governing system of a steam turbine. The system consists of the following components:

Fly ball speed governor: This is the heart of the system which senses the change in speed (frequency). As the speed increases the fly balls move outwards and the point B on linkage mechanism moves downwards. The reverse happens when the speed decreases.

Hydraulic amplifier: It comprises a pilot valve and main piston arrangement. Low power level valve movement is converted into high power level piston valve movement. This is necessary in order to open or close the steam valve against high pressure steam.

Linkage mechanism: ABC is a rigid link pivoted at B and CDE is another rigid link pivoted at D. This link mechanism provides a movement to the control valve in proportion to change in speed. It also provides a feedback from the steam valve movement.

Speed changer: It provides a steady state power output setting for the turbine. Its downward movement opens the upper pilot valve so that more steam is admitted to the turbine under steady conditions (hence more steady power output). The reverse happens for upward movement of speed changer.

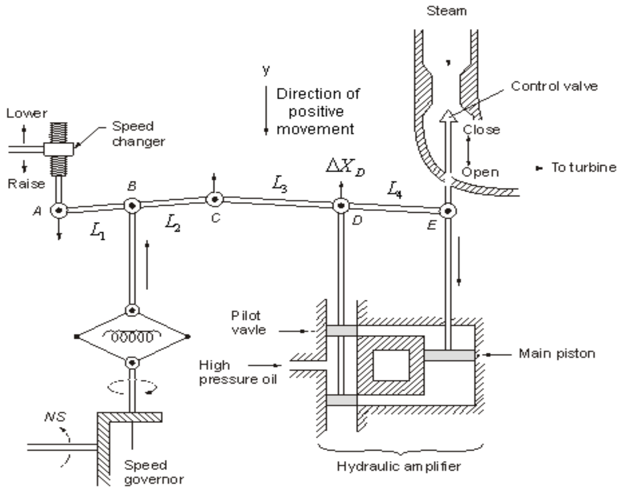


Fig. 1. Model of Turbine speed governing system

V.PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Kennedy and Dr. Eberhart in 1995, inspired by social behavior of bird flocking or fish schooling. PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. The detailed information will be given in following sections. Compared to GA, the advantages of PSO are that PSO is easy to implement and there are few parameters to adjust. PSO has been successfully applied in many areas: function optimization, artificial neural network training, fuzzy system control, and other areas where GA can be applied.PSO as an optimization tool, provides a population-based search procedure in which individuals called particles change their position(states) with time. In a PSO system, particles fly around in a multi-dimensional search space. During flight, each particle adjusts its position according to its own experience and the experience of neighboring particles, making use of the best position encountered by it and neighbors. The swarm direction of a particle is defined by the set of particles neighboring the particle and its history experience. Instead of using evolutionary operation to manipulate the individuals, like in other evolutionary computational algorithms, each individual in PSO flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions flying experience. Let p and v denote a particle’s co-ordinate (position) and its corresponding flight speed (velocity) in a search space respectively.

VI.RESULT

Integral controller gains at each area in the two-area system in deregulated operation are optimized using PSO. The simulation is done using MATLAB metafile. The cost function J obtains using (1) is given to the PSO technique.

Sampling time is chosen as 0.2s. In case 1, the two optimum values of integral gains found are $K_{I1} = 1$ and $K_{I2} = 0.1556$. The dynamic responses of frequency and tie-line power are shown in Fig. 2 (a)-(c). In case 2, the two optimum values of integral gains found are $K_{I1} = 0.0377$ and $K_{I2} = 0.6032$. The dynamic responses of frequency and tie-line power are shown in Fig 5.4. (a)-(c).In case 3, the two optimum values of integral gains found are $K_{I1} = 1.5$ and $K_{I2} = 0.9069$. The dynamic responses of frequency and tie-line power are shown in Fig 4 (a) - (c).

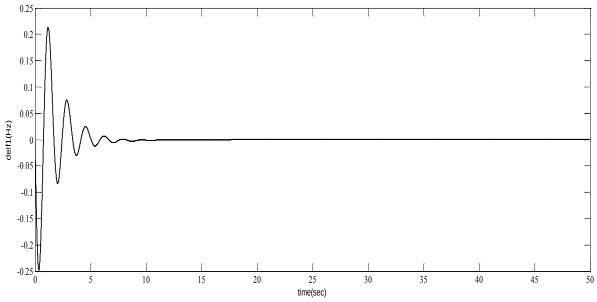


Fig. 2

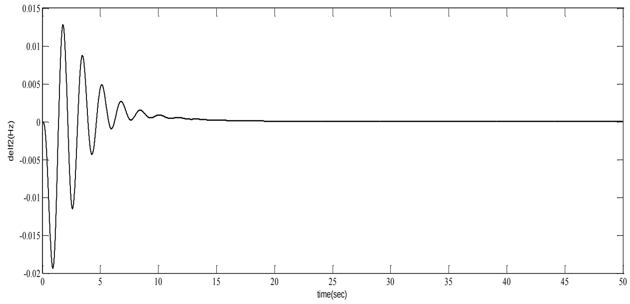


Fig. 3

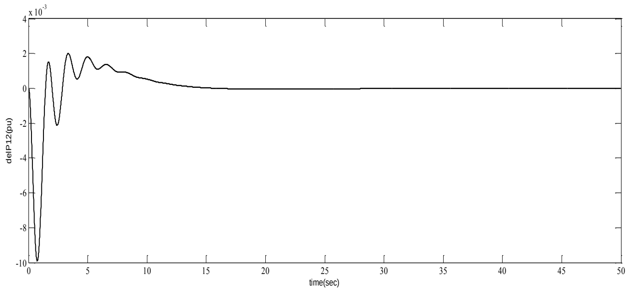
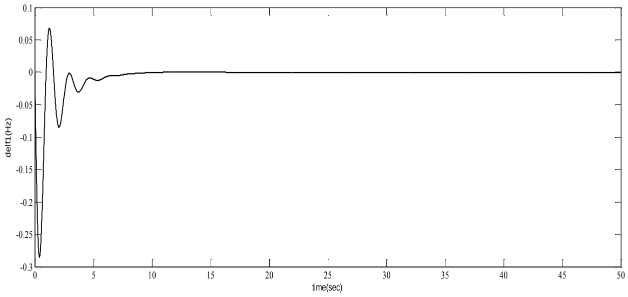


Fig. 4



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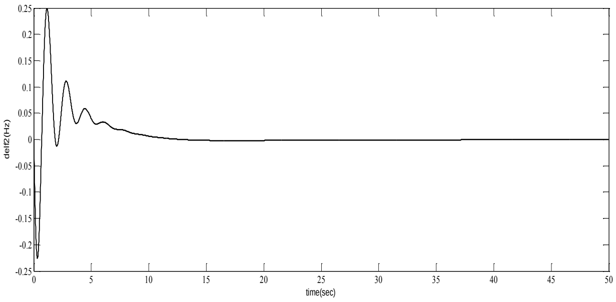

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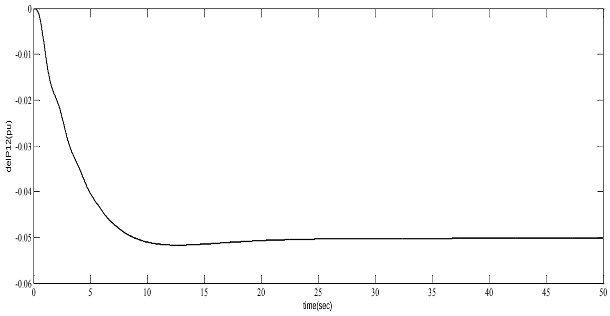

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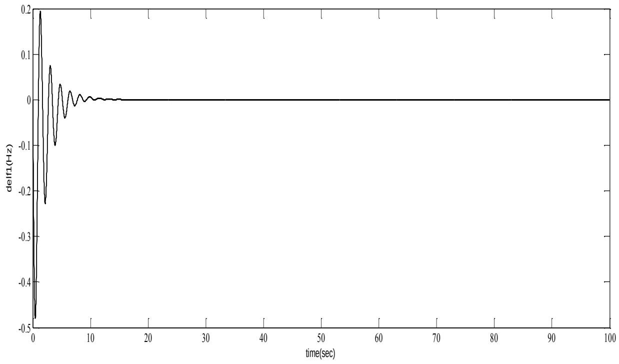

Fig. 8

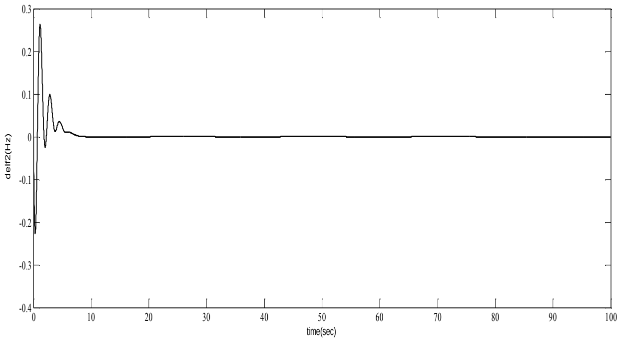

Fig. 9

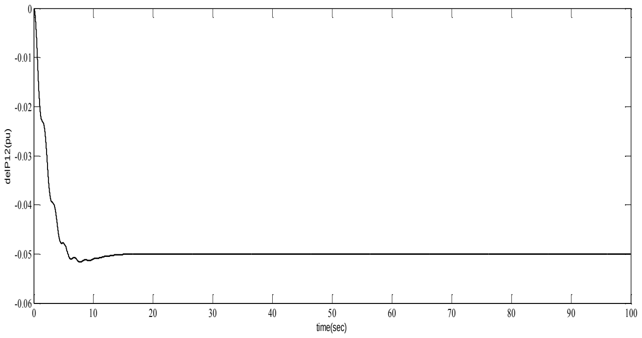

Fig. 10

VII. CONCLUSION

In this AGC of an interconnected power system after deregulation is presented. PSO technique is used to optimize the controller gains. In deregulated environment, bilateral contracts between DISCOs in one control area and GENCOs in another control area are considered. The elements of DPM are chosen in accordance with bilateral contracts. The AGC is studied for different possible contracts in deregulated environment. The scheduled flow on a tie-line between two control areas matches with the contract directions. The dynamic responses obtained for different possible contracts satisfy the AGC requirements.

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