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Hybrid Neuro Fuzzy approach for automatic generation control in restructured power system

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ABSTRACT

In this paper, a hybrid combination of Neuro and Fuzzy is proposed as a controller to solve the Automatic Generation Control (AGC) problem in a restructured power system that operates under deregulation pedestal on the bilateral policy. In each control area, the effects of the possible contracts are treated as a set of new input signal in a modified traditional dynamical model. The prominent advantage of this strategy is its high insensitivity to large load changes and disturbances in the presence of plant parameter discrepancy and system nonlinearities. This newly developed strategy leads to a flexible controller with a simple structure that is easy to implement and consequently it can be constructive for the real world power system. The proposed method is tested on a three-area hydro-thermal power system in consideration with Generation Rate Constraint (GRC) for different contracted scenarios under diverse operating conditions. The results of the proposed controller are evaluated with the Hybrid Particle Swarm Optimisation (HCPSO), Real Coded Genetic Algorithm (RCGA) and Artificial Neural Network (ANN) controllers to illustrate its robust performance.

Introduction

The electric power trade at present is largely in the hands of Vertically Integrated Utilities (VIU) which possess generation, transmission and distribution systems facilitates to supply power to the customer at regulated tariff. The major revolutionize that has arises be the emergence of Independent Power Producer (IPP) that can sell power to VIU. Given the present situation, it is generally agreed that the first step in deregulation will be to separate the generation of power from the transmission and distribution, thus putting all the generation on the same footing as the IPP. In an interconnected power system, a sudden load perturbation in any area causes the deviation of frequencies of all the areas and also in the tie-line powers.

This has to be corrected to ensure the generation and distribution of electric power with good quality. This is accomplished by Automatic Generation Control (AGC). The main objectives of AGC [10,11] are to be maintained the desired MegaWatt output and the nominal frequency in an interconnected power system besides maintaining the net interchange of power between control areas at predetermined values. The AGC task is carried out through the error signal produced during generation and net interchange between the areas (i.e.,) Area Control Error (ACE) [27].

$$\mathrm{ACE} = \sum_{j} (\Delta P_{\mathrm{tie},i,j} + b_i \Delta f_i) \tag{1}$$

where b_i be the frequency bias coefficient of the ith area, Δf_i be the frequency error of the ith area, $\Delta P_{\mathrm{tie},i,j}$ be the tie line power flow error between ith area and jth area. With the restructuring of electric utilities, AGC requirements should be expanded to include the planning functions necessary to ensure the resources needed for AGC implementation are within the functional requirements. So most of the methods that may be proposed must have a good ability to track the contracted or uncontracted demands and can be used in a practical environment. A lot of studies have been made about AGC in a restructured power industry over last decades. These studies try to modify the conventional LFC system [30] to take into account the effect of bilateral contracts on the dynamics [12] and improve the dynamical transient response of the system under competitive conditions [9,18,19]. This paper proposes a control scheme that guarantees a minimum transient deviation and ensures zero steady state error. The stabilization of frequency oscillations in an interconnected power system [26] becomes challenging when implements in the future competitive environment. Consequently

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Nomenclature

i	subscript referred to area	R	droop characteristic
F	area frequency	B	frequency bias
P_{tie}	tie line power flow	FD	frequency deviation
P_T	turbine power	T_{ij}	tieline synchronizing coefficient between areas i&j
P_V	governor valve position	P_d	area load disturbance
P_C	governor set point	P_{Lji}	contracted demand of DISCO j in area i
ACE	area control error	P_{ULji}	un-contracted demand of DISCO j in area i
cpf	contract participation factor	$P_{M,ji}$	power generation of GENCO j in area i
gpf	generation participation factor	P_{Loc}	total local demand
K_P	subsystem equivalent gain constant	η	area interface
T_P	subsystem equivalent time constant	ξ	scheduled power tie line power flow deviation
T_T	turbine time constant	GRC	Generation Rate Constraint
T_G	governor time constant	DPM	DISCO participation matrix

advanced economic, high efficiency and improved control schemes [21,22] are required to ensure the power system reliability. The conventional load-frequency controller may no longer be able to attenuate the large frequency oscillation due to the slow response of the governor [24,25]. A number of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance [31,32]. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller [30–32]. Conventional controller is simple for implementation but takes more time and gives large frequency deviation. A number of state feedback controllers based on linear optimal control theory have been proposed to achieve enhanced performance [20,8]. Fixed gain controllers are designed at nominal operating conditions and fail to provide best control performance over a wide range of operating conditions [17]. Subsequently, to keep system performance near its optimum, it is desirable to track the operating conditions and use updated parameters to compute the control. Adaptive controllers with self-adjusting gain settings have been proposed for LFC [4,8,13–15]. There has also been considerable research work attempting to propose better AGC systems based on modern control theory [20], neural network [2,3,5,6,29] fuzzy system theory [4] and reinforcement learning [7]. Recent study confirms that ANFIS approach has also been applied to hydrothermal system [16,23,28]. All research during the earlier period in the area of AGC narrates interconnected two equal area thermal system and petite attention has been paid to AGC of unequal multi area systems [1]. Most of ancient time works have been centered in the region of the design of governor secondary controllers, and design of governor primary control loop. Apparently no literature has discussed AGC performance subject to simultaneous small step load perturbations in all area or the application of ANFIS technique to a multi-area power system. The escalation in size and convolution of electric power systems along with increase in power demand has necessitated the use of intelligent systems that combine knowledge, techniques and methodologies from various sources for the real-time control of power systems.

In this paper, an effort has been made to apply Hybrid Neuro-Fuzzy (HNF) controller for the automatic load frequency control for the three area hydro-thermal restructured power system in consideration with GRC. The simulations are carried out in presence of the GRC's because ignoring GRC show the way to non-realistic results.

System analyzed

In this multi source generating system, there are three control areas (Fig. 1) in which each areas has different combinations of GENCOs and DISCOs. Area 1 comprises of three GENCOs with thermal power system of reheat and non reheat turbine combinations and two DISCOs, Area 2 comprises of two GENCOs with hydro and thermal (non reheat turbine) combination and one DISCO, Area 3 consists of two GENCOs with hydro and thermal (reheat turbine) combination and two DISCOs as shown in Fig. 2. In this restructured environment, any GENCO in one area may supply DISCOs in the same area as well as DISCOs in other areas. In other words, for restructured system having several GENCOs and DISCOs, any DISCO may contract with any GENCO in another control area independently. This is called as "Bilateral Transaction". The transactions have to be carried out through an independent system operator (ISO). The main purpose of ISO is to control many ancillary services, one of which is AGC. In open access scenario, any DISCO has the freedom to purchase MW power at competitive price from different GENCOs, which may or may not have contract with the same area as the DISCO. The contracts of GENCOs and DISCOs described by 'DISCO participation matrix' (DPM). The DPM for the n th area power system is as follows:

$$\text{DPM} = \begin{pmatrix} cpf_{11} & cpf_{12} & \dots & cpf_{1n} \\ cpf_{21} & cpf_{22} & \dots & cpf_{2n} \\ \vdots & \vdots & \dots & \vdots \\ cpf_{n1} & cpf_{n2} & \dots & cpf_{nn} \end{pmatrix} \tag{2}$$

In DPM, the number of rows is equal to the number of GENCOs and the number of columns is equal to the number of DISCOs in the system. Any entry of this matrix is a fraction of total load power contracted by a DISCO toward a GENCO [24]. The sum of total entries in a column corresponds to one DISCO be equal to one (i.e.,) $\sum_{j=1}^{n} cpf_{ij} = 1$

$$\text{AGPM} = \begin{pmatrix} \text{AGPM}_{11} & \text{AGPM}_{12} & \dots & \text{AGPM}_{1N} \\ \text{AGPM}_{21} & \text{AGPM}_{22} & \dots & \text{AGPM}_{2N} \\ \vdots & \vdots & \dots & \vdots \\ \text{AGPM}_{N1} & \text{AGPM}_{N2} & \dots & \text{AGPM}_{NN} \end{pmatrix} \tag{3}$$

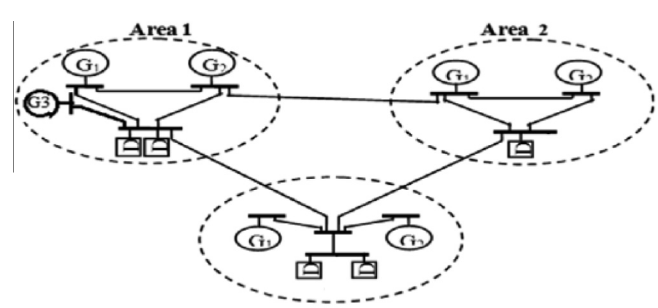

Fig. 1. Three area restructured power system.