

Fuzzy logic controller in interconnected electrical power systems for load-frequency control

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Abstract

This study presents an application of a fuzzy gain scheduled proportional and integral (FGPI) controller for load-frequency control of a two-area electrical interconnected power system. Model simulations of the power system show that the proposed FGPI controller is effective and suitable for damping out oscillations resulted from load perturbations. The current FGPI results were compared against those from a conventional proportional and integral (PI) controller, a fuzzy logic controller and a FGPI controller proposed by Chang and Fu (Chang C. S., Fu W. Area load-frequency control using fuzzy gain scheduling of PI controllers. *Electr Power syst Res* 1997; 42: pp. 145–152). Two performance criteria were utilized for the comparison: settling times and overshoots of the frequency deviation and absolute error integral. The comparison study indicated that the proposed FGPI controller has better performance than the other three controllers.

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1. Introduction

In power systems, active and reactive power flows function independently. Therefore, different control blocks are used to control them. The automatic generation control (AGC) is the major technique for solving this problem [1]. Interconnected electrical power systems operate together adjusting their power flows and frequencies at all areas by AGC. In this study, a two-area power system is considered to control power flows. A power system has a dynamic characteristic meaning that it can be affected by disturbances and changes at the operating point [2,3]. Given that frequencies at the areas and power flows in tie-lines produce unpredictable load changes and also, generated and demand powers are not equal. Such difficulties are taken care of by AGC systems which are also called load-frequency control (LFC) and are being improved over the years [4]. Load-frequency control, a technical requirement for the proper

operation of an interconnected power system, is very important for supplying reliable electric power with good quality. The goals of the LFC are to maintain zero steady state errors in a multi-area interconnected power system and to fulfill the requested dispatch conditions [5].

During last decades, several studies on the load-frequency control in interconnected power systems have been presented in the literature. Different control strategies have been suggested based on the conventional linear control theory [6–8], among others. Since, the dynamics of a power system even for a reduced mathematical model is usually nonlinear, time-variant and governed by strong cross-couplings of the input variables, the controllers have to be designed with special care [9]. Thus, a gain scheduling controller had been used for nonlinear systems by some researcher e.g. [5]. In this method, control parameters can be changed very quickly since parameter estimation is not required, and thus system outputs are obtained faster with higher quality as compared with conventional controllers. However, in the same method, the transient response can be unstable because of abruptness in system parameters. Also, accurate linear time invariant models cannot be obtained at variable operating points [5].

Recently, FGPI controllers have been proposed to solve the above mentioned difficulties in power systems. For

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Nomenclature

K_i	integral gain constant	$d(t)$	disturbance vector
K_p	proportional gain constant	Δf_i	frequency deviation from nominal value in Area- i
R_i	regulation constant	ΔP_{12}	change in tie-line power between two-area
T_g	speed governor time constant	$\Delta P_{d,i} = \Delta P_{L,i}$	load demand increment in Area i
T_t	turbine time constant	b_i	frequency bias factor in Area i
T_p	power system time constant	T_a	settling time of proposed controller
A	system matrix	T_b	settling time of the conventional PI controller
B	input matrix	T_c	settling time of the conventional I controller
L	disturbance matrix	T_d	settling time of the fuzzy logic controller
$x(t)$	state vector	a_{12}	synchronizing power coefficient
$u(t)$	control vector		

example, [5] and [10] developed different fuzzy rules for the proportional and integral gains separately and showed that response of power systems can be further improved using fuzzy logic controller [11].

In this study, a FGPI controller was designed with seven triangular membership functions to LFC application in a two-area power system for generating electricity with good quality. In the design of the controller, rules for the gains (K_p and K_i) are chosen to be identical in order to improve the system performance. The proposed controller was compared with three different controllers: a conventional PI controller, a fuzzy logic controller and another FGPI controller designed by [5]. Settling times and overshoots of the systems and absolute integral values were utilized as comparison criteria to evaluate the performance of controllers. It was shown that the proposed FGPI controller generally has better performance than the other controllers.

2. Interconnected electrical power systems

Interconnected power systems consist of many control areas connected by tie-lines. The block scheme of an uncontrolled two-area power system is shown in Fig. 1.

All blocks are generally nonlinear, time-variant and/or non-minimum phase systems [12]. In each control area, the generators are assumed to form a coherent group. Loads changing at operating point affect both frequencies in all areas and tie-line power flow between the areas [13]. As known that power systems have parametric uncertainties and they must have small oscillations in the magnitude of transient frequency. Their speed control must be taken care of as quickly as possible [12]. The load-frequency control generally is accomplished by two different control actions in interconnected two-area power systems: (a) the primary speed control and (b) supplementary or secondary speed control actions. The former performs the initial vulgar readjustment of the frequency by which generators in the control area track a load variation and share it in proportion to their capacities. This process typically takes place within 2–20 s. The latter takes over the fine adjustment of the frequency by resetting the frequency error to zero through an integral action. The relationship between the speed and load can be adjusted by changing a load reference set point input. In practice, the adjustment of the load reference set point is accomplished by operating the speed changer motor. The output of each unit at a given system frequency can be varied only by changing its load reference, which in effect moves the speed-droop characteristic up and down.

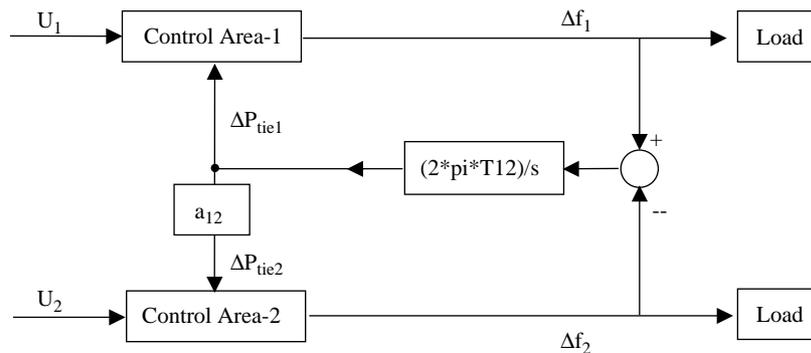


Fig. 1. The block scheme of an uncontrolled two-area power system.

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