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Fuzzy Logic Based Automatic Load Frequency Control of Two Area Power System With GRC

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Abstract

This paper describes the Automatic Generation Control (AGC) of interconnected reheat thermal system using Proportional - Integral (PI) and extended Proportional - Integral (extended PI) and Fuzzy Logic Controller (FLC). The extended PI controller is used to reduce the peak over shoot and settling time error in the past. The action of this controller provides satisfactory operation when compared to the PI scheme even with the consideration of non-linearity such as Generation Rate Constraint (GRC). This extended PI controller is greatly dependent on the decaying factor. The value of decaying factor should be carefully chosen otherwise it greatly affects the control performance. To overcome this drawback Fuzzy Logic Controller has been employed in the system. The aim of the FLC is to restore the frequency and tie-line power in very smooth way to its nominal value in the shortest possible time, if any load change occurs. The performance of FLC has been compared with PI and extended PI control in the presence of Generation Rate Constraint (GRC). System performance is examined considering 1% step load perturbation in either area of the system.

Keywords: Area Control Error (ACE), Fuzzy Logic Controller (FLC), Generation Rate Constraint (GRC), Load Frequency Control (LFC), Proportional-Integral (PI).

Introduction

In electric power generation, system disturbances due to load fluctuations tend to variation in desired frequency value. Automatic Generation Control (AGC) or Load Frequency Control is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. An interconnected power system can be considered as being divided into control areas, which are connected by the tie lines. In each control area, all generators are assumed to form a coherent group. The power system is subjected to local variations of random magnitude and duration. For satisfactory operation of a power system the frequency should remain nearly constant. The frequency of a system depends on active power balance. As frequency is a common factor throughout the system, a change in active power demand at one point is reflected through out the system. Many investigations have been reported in the past pertaining to LFC of a multi area interconnected power system [1]. In the literature, some control strategies have been proposed based on classical control theory. Due to unnecessary errors in the past, the conventional PI control scheme does not provide adequate control performance with the presence of non-linearity. This paper develops an extended PI control to the AGC scheme with the consideration of GRC in order to reduce the overshoot of the conventional PI controller. The basic idea of extended PI controller is decaying factor, which reduces the effects of the error in the past. For an optimal or near optimal performance, it is necessary that the decaying factor as well as the feed back gain should be changed very quickly in response to change in the system dynamics. However due to inherent characteristics of changing load and the system non-linearities it is very difficult to obtain the optimum value of decaying factor [2]. The difficulty in obtaining the optimum settling time of previously said controller is mitigated by using FLC, which gives the opportunity to describe the control action in qualitative term and symbolic form.

Literature survey shows that [4], only a few investigations have been carried out using FLC to LFC. It has been discussed that the implementation of such FLC has greatly improved the performance of the controller “without negatively affecting the consumers’ quality of supply”. This paper addresses the comparison between the performances of FLC and extended PI controller, which is priorly compared with PI control in the presence of non-linearity. The transfer function model of two area interconnected reheat thermal system is shown in the Fig.1.

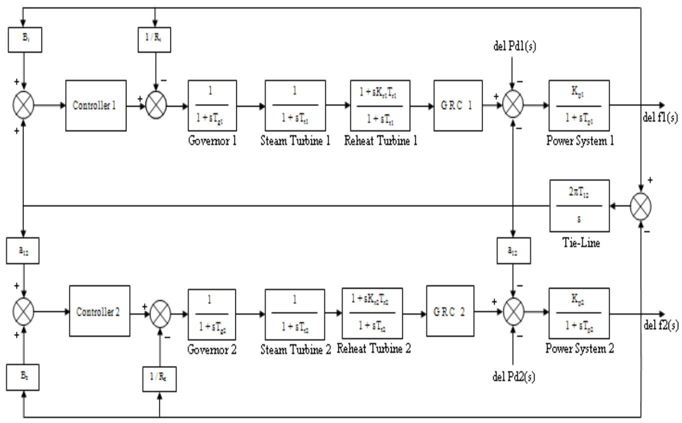

Figure 1: Transfer Function Model of Two area Thermal Interconnected System.

System Investigated

System investigation has been carried out on a two equal area reheat thermal power system considering GRC. The nominal parameters of the system are given in appendix. Matlab version 7.1 has been used to obtain dynamic response of change in frequencies ΔF_1, ΔF_2 and ΔP_{tie} for 1% step load perturbation. Proper assumptions and approximations are made to linearize the mathematical equations which describe the system and transfer function model [3].

In practical steam turbine system due to thermodynamic and mechanical constraints, there is a limit to the rate at which its output power can be changed. This limit is referred to as GRC.

Rate limits are imposed to avoid a wide variation in process variables like temperature and pressure for the safety of equipment. Generation Rate Constraint of 3% p.u.MW/min are usually applied to reheat turbines. [1]

A. Conventional PI Controller

For Conventional PI Controller, gain K_p & K_i has been optimized using Integral Square Error (ISE) criterion. For ISE technique, the objective function used is

$$J = \int (\Delta P_{tie}{}^2 + \Delta F_i{}^2) \Delta T \qquad (1)$$

i = 1,2,…,n

Where, ΔF = change in frequency and

ΔP_{tie}= change in tie line power.

The two area thermal system is simulated with PI controllers. The dynamic response of the system does not yield good control performance with the consideration of non-linearity such as GRC. The simulation results are shown in the Fig. 3 a-c

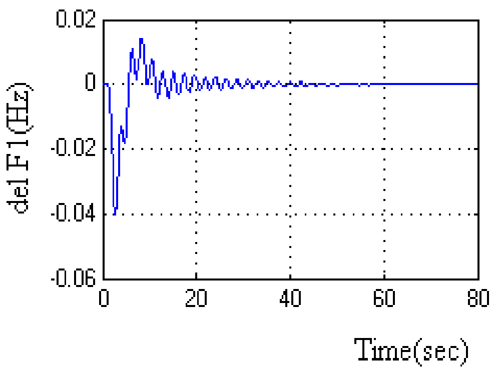

Figure 3a: delF1 with GRC with PI.

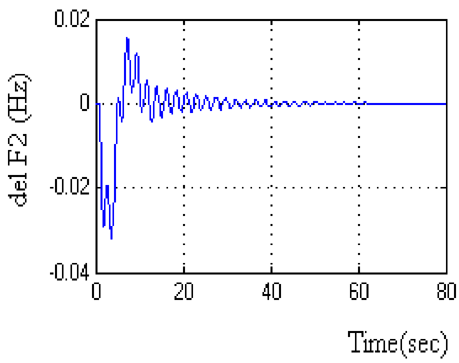

Figure 3b: delF2 with GRC with PI.

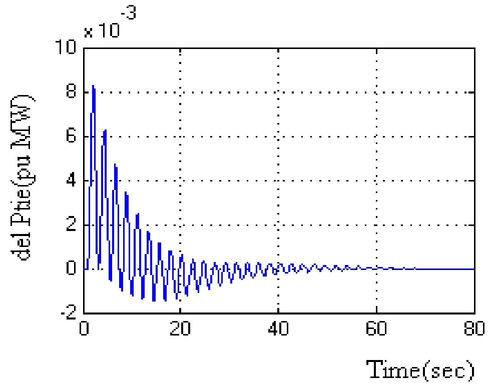

Figure 3c: del P_{tie} with GRC with PI.

B. Conventional Extended PI Controller

The extended PI term is substituted for general PI term in conventional scheme. In this control scheme an exponential decaying function (λ) is chosen as follows,

$$h(t) = e^{-\lambda t}\, u(t) \tag{2}$$

The extended integral control is given by,

$$\int_0^t e^{-\lambda(t-\tau)} \Delta f(\tau) d\tau \tag{3}$$

with its s-domain function of $\dfrac{1}{(s+\lambda)}$

The decaying factor of extended PI varies in proportion to the degree of deviation of feedback signals. For large overshoot, large value of decaying factor should be selected to reduce the effects of the error, while small decaying factor for small error. The simulation results are shown in the Fig.4 a-c

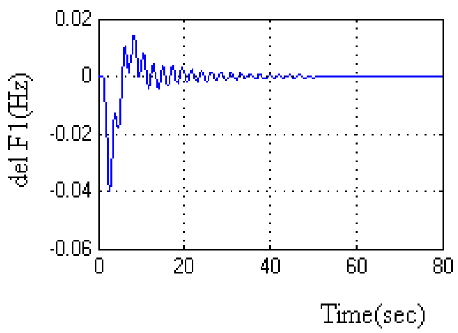

Figure 4a: delF1 with GRC with Ext PI.

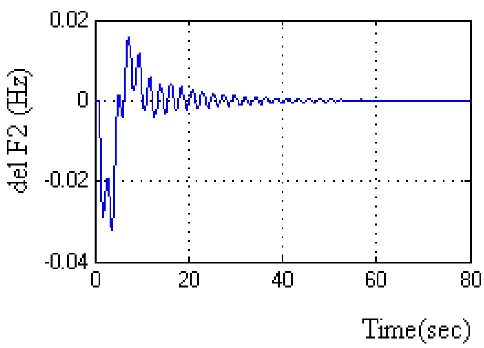

Figure 4b: delF2 with GRC with Ext PI.

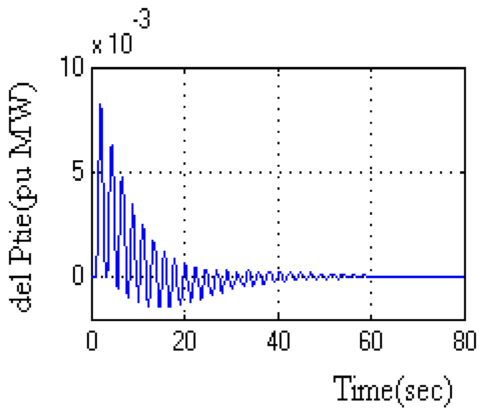

Figure 4c: del P_{tie} with GRC with Ext PI.

Fuzzy Logic Controller

The concept of fuzzy logic was developed by Lotfi.A.Zadeh in 1965 to address uncertainty and imprecision which widely exists in engineering problems [5]. The design of FLC can be normally divided into three areas namely allocation of area of inputs, determination of rules and defuzzifying of output into a real value. In this paper the proposed fuzzy controller takes the input as ACE and $\dot{ACE}$, which is given as,

$$ACE_i = \Delta F_i B_i + \Delta P_{tie_i} \tag{4}$$

The Block diagram of Fuzzy Logic Controller is shown in Fig.4. [4] Seven Membership Functions (MF) have been used to explore the best settling time.

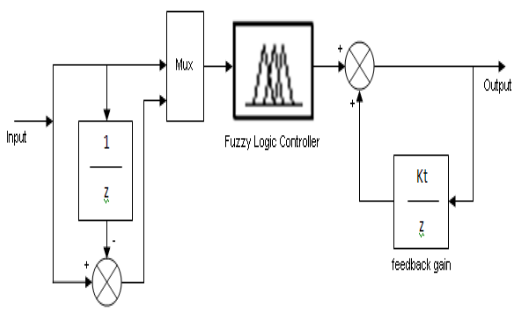

Figure 4: Fuzzy Logic Controller.

MF specifies the degree to which a given input belongs to a set. Here five membership functions namely Negative Big (NB), Negative Medium (NM), Negative

Small (NS), Zero (ZO), Positive Small (PS), Positive Medium (PM), Positive Big (PB) are used.

If ACE is NB and $A\dot{C}E$ is ZO then output is NS.

Defuzzification to obtain crisp value of FLC output is done by center of area method. Fuzzy rules specify the relationship among the fuzzy variables. These rules help us to explain the control action in qualitative terms. Rules are given in Table 1.

Table 1: Fuzzy Rules.

ACE								
		NB	NM	NS	ZO	PS	PM	PB
	NB	PB	PB	PB	PB	PM	PM	PS
	NM	PB	PM	PM	PM	PS	PS	PS
	NS	PM	PM	PS	PS	PS	PS	ZO
$A\dot{C}E$	ZO	NS	NS	NS	ZO	PS	PS	PS
	PS	ZO	NS	NS	NS	NS	NM	NM
	PM	NS	NS	NM	NM	NM	NB	NB
	PB	NS	NM	NB	NB	NB	NB	NB

Simulation Results

The system is simulated for a step load disturbance of 1% on either area. Due to this the change in dynamic response of the system has been observed in the presence of GRC. The simulation results of the system with FLC are shown in Fig.5 a-c. Finally the simulation results of two-area system with FLC have been compared with extended PI control. FLC yields fast settling time with less number of oscillations which advocates the smooth settlement of the quality power supply even with the consideration of non-linearity.

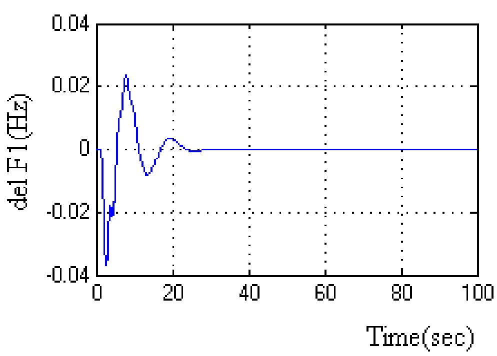

Figure 5a: delF1 with GRC with Fuzzy.

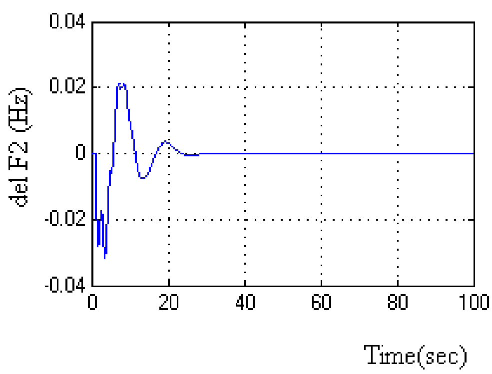

Figure 5b: delF2 with GRC with Fuzzy.

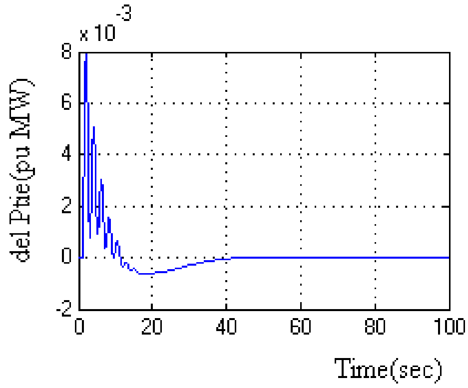

Figure 5c: del P_{tie} with GRC with Fuzzy.

Conclusion

In this paper FLC is designed for automatic load frequency control of two area interconnected power system. The system performance is observed on the basis of dynamic parameter (i.e.) settling time. The comparison of the dynamic responses of proposed controllers is shown in table 2. The simulation result shows that the FLC yields much improved control performance when compared to both extended PI and conventional PI controller.

Table 2: Comparison Study of Settling time.

Non-Linearity	Controllers	ΔF_1	ΔF_2	ΔP_{tie}
With GRC	Fuzzy	25s	25s	40s
	Ext PI	50s	53s	58s
	PI	57s	62s	70s

Appendix

P_{ri} = 2000 MW
T_{ti} = 0.3s
T_{gi} = 0.08s
K_r = 0.5
T_{ri} = 10s
K_{pi} = 120 Hz/pu MW
T_{pi} = 20 s
T_{12} = 0.086
R_i = 2.4 Hz/ pu MW
f = 60 Hz
B_i = 0.425 pu MW/Hz

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