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Fuzzy Logic based Automatic Generation Control of Interconnected Power System

Gursharan Kaur,
Student, M tech, Power Engineering,
BBSBEC

Amarjeet Kaur,
Assistant professor,
Electrical Engineering Department,
BBSBEC

***Abstract* - The main role of automatic generation control (AGC) is to maintain system frequency and tie line flow at their scheduled values during normal period in an interconnected system. This paper presents the automatic generation control of an interconnected two area thermal reheat system using conventional and fuzzy logic controller. Change in generation in both areas and change in overall frequency of system is examined using MATLAB SIMULINK. Area control error (ACE) is measured and results of conventional methods and fuzzy logic are compared. The aim of proposed controller is to restore the system frequency to its nominal value in smallest possible time whenever there is any change in load demand.**

Keywords* - *Automatic generation control, Area control error, Fuzzy logic controller, Load frequency control. Generation Rate Constraints

I. INTRODUCTION

Power systems are used to convert natural energy into electric power and are interconnected to provide secure and economical operations. They transmit electricity to factories and houses to satisfy all kinds of power needs. To optimize the performance of electrical equipment, it is important to ensure the quality of the electric power. During the transmission, both the active power balance and the reactive power balance must be maintained between generating and utilizing the AC power. Those two balances correspond to two equilibrium points: frequency and voltage. A good quality of the electric power system requires both the frequency and voltage to remain at standard values during operation. It will be impossible to maintain the balances of both the active and reactive powers without control. As a result of imbalance, the frequency and voltage levels vary with the changing load. Thus a control system is essential to cancel the effects of the random load changes and to keep the frequency and voltage at the standard values. The control problem of the frequency and voltage can be decoupled. The frequency is dependent on the active power while the voltage is dependent on the reactive power and the active power and frequency control is referred to as load frequency control (LFC). [1]

When area load changes and abnormal fault conditions occurs the system frequency and scheduled power interchange between them which is to required to be controlled in order to normalize the system frequency and tie line power interchange thus meeting the power demands. For this the Automatic Generation Control (AGC) is one of the essential control that considers the sudden and small load perturbations. The analysis and design of Automatic Generation Control (AGC) system of individual generator eventually controlling large interconnection between different control areas plays a vital role in automation of power system. The purpose of AGC is to maintain system frequency very close to a specified nominal value to maintain generation of individual unit's at the most economical value. Many investigations in the area of Load Frequency Control (LFC) problem of interconnected power system using different controllers have been carried out successfully among which the most widely employed are the conventional proportional integral (PI) and proportional integral derivative (PID) controllers. [2]

II. PROBLEM FORMULATION

An inter-connected power system is considered in the present study to design the fuzzy controller. The system comprises of two-area thermal system provided with supplementary controllers. A step load perturbation of nominal loading has been considered in area-1. Small perturbation transfer function block diagram of a two-area reheat thermal system is shown in Fig. 1 [2]. Here, the tieline power deviations can be assumed as an additional power disturbance to any area k. For the load frequency control, the proportional integral controller is implemented.

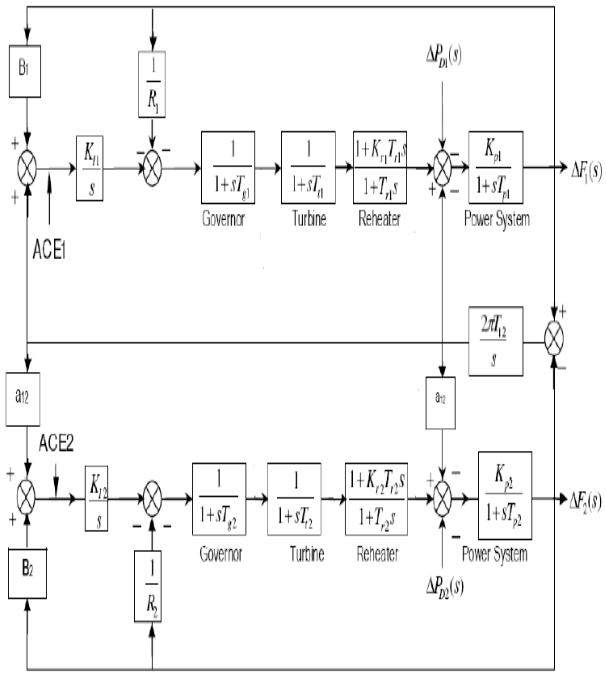

Fig.1: Transfer function model of two-area reheat thermal system

Load Frequency Control with GRC: Load frequency control problem discussed so far does not consider the effect of the restrictions on the rate of change of power generation. In power systems having steam plants, power generation can change only at a specified maximum rate. The generation rate (from safety considerations of the equipment) for reheat units is quite low. Most of the reheat units have a generation rate around 3% / minute. Some have a generation rate between 5 to 10% / minute. If these constraints are not considered, system is likely to chase large momentary disturbances. This results in undue wear and tear of the controller. Several methods have been proposed to consider the effect of GRC for the design of automatic generation controllers. When GRC is considered, the system dynamic model becomes non-linear, and linear control techniques cannot be applied for the optimization of the controller setting [7,8].

If the generation rates are included in the state vector, the system order will be altered. Instead of augmenting them, while solving the state equations, it may be verified at each step, if GRCs are violated. Another way of considering GRCs for both areas is to add limiters to the governors as shown in Fig.2.

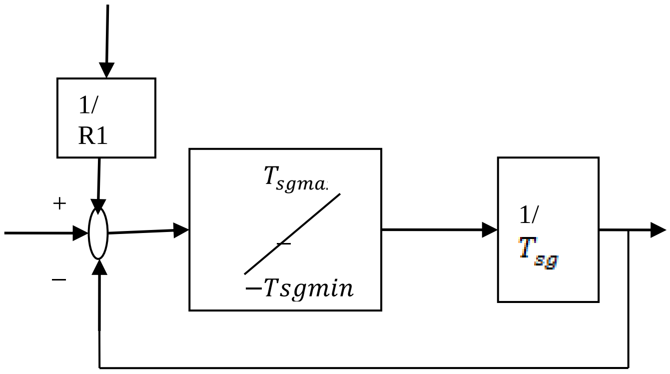

Fig.2: Governor Model with GRC

III. OBJECTIVES

In this work, a control strategy has been used to remove area control error (ACE) and to maintain the tie-line power flow at their scheduled values during normal period in an interconnected power system.

This paper presents the automatic generation control (AGC) of an interconnected two area system. The inputs of the proposed Fuzzy controllers are area control error (ACE), and change of frequency (ΔF).

IV. METHODOLOGY

A. Fuzzy Logic Controller

First-generation (non-adaptive) simple fuzzy controllers can generally be depicted by a block diagram as shown in Fig. 3. The knowledge-base module in Fig. 3 contains knowledge about all the input and output fuzzy partitions. It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control[5,11]. The steps in designing a simple fuzzy control system are as follows:

1. Identify the variables (inputs, states, and outputs) of the plant.
2. Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe).
3. Assign or determine a membership function for each fuzzy subset.
4. Assign the fuzzy relationships between the inputs' or states' fuzzy subsets on the one hand and the outputs' fuzzy subsets on the other hand, thus forming the rule-base.
5. Choose appropriate scaling factors for the input and output variables in order to normalize the variables to the [0, 1] or the [−1, 1] interval.
6. Fuzzify the inputs to the controller.
7. Use fuzzy approximate reasoning to infer the output contributed from each rule.
8. Aggregate the fuzzy outputs recommended by each rule.
9. Apply defuzzification to form a crisp output.

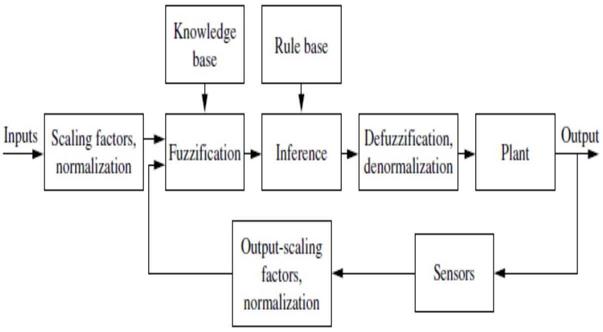

Fig.3: A simple fuzzy logic control system block diagram

The functions of the above modules are described below.

(i) The Fuzzification:

a) Measure the values of input variables
b) Performs a scale mapping that transforms the range of values of input variables into corresponding universe of discourse.
c) Performs the function of Fuzzification that converts input into suitable linguistic values, which may be, viewed labels of fuzzy sets.

(ii) The Knowledge Base:

It consists of data base and linguistic control rule base.

a) The database provides necessary definitions, which are used to define linguistic control rules and fuzzy data, manipulation in an, FLC.
b) The rule base characterizes the control goals and control policy of the domain experts by means of set of linguistic control rules.

(iii) The Decision Making Logic**:**

It is the kernel of an FLC; it has the capability of simulating human decision making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.

(iv)The Defuzzification:

(a) A scale mapping which converts the range of values of input variables into corresponding universe of discourse.

(b) Defuzzification, which yields a non-fuzzy, control action from an inferred fuzzy control action.

B. *System Model*

A two-area reheat type thermal system consists of two single areas connected through a power line called the tie-line as shown in Fig.1. The simulink model of the system considered is depicted in Fig.4 below. Each area feeds its user pool and tie-line allows the electric power to flow between areas [2]

Since both areas are tied together, a load agitation in one area affects the output frequencies of both areas as well as the power flow on the tie-line. In the above Fig., reheat and generation rate constraints (GRC) are considered. GRC inclusion increases the system non-linearity much more and if in that condition, the controller used responds more precisely to have more stable response, then linearization is achieved in a non-linear environment.

Investigations have been carried out on an interconnected two area thermal system provided with reheat type of turbine with GRC. For carrying out AGC for the two area system conventional and fuzzy logic controller is used in and change in generation in both the areas and change in overall error of the system is examined using MATLAB SIMULINK. The responses have been studied for Δf1, Δf2, ΔPtie. Area Control Error (ACE) is measured and results of the conventional method and the fuzzy logic are compared. The aim of the proposed controller is to restore the change in error to its nominal value in the smallest possible time whenever there is any change in the load demand etc.

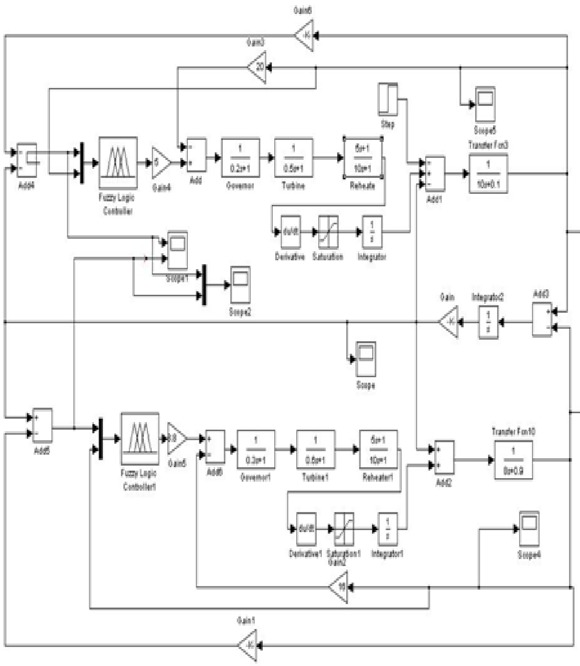

Fig. 4. Simulink model with Fuzzy Logic controller

The control rules are formulated in linguistic terms using fuzzy sets to describe the magnitude of error, the frequency deviation and the magnitude of the appropriate control action. The membership functions used are as:

NL = negative large
NS = negative small
ZE = zero
PS = positive small
PL = positive large

The rule table thus formed for the above membership functions using the inputs is drawn out to be as follows;

Table 1: Fuzzy Rule Table

ACE / d/dt(F)	NL	NS	ZE	PS	PL
NL	NL	NL	NS	NS	ZE
NS	NL	NL	NS	ZE	ZE
ZE	NS	NS	ZE	PS	PS
PS	ZE	PS	PS	PL	PL
PL	ZE	ZE	PS	PL	PL

V. RESULTS

The simulink model shown in Fig.4 using the fuzzy logic controller at the input to study out the system response gives the outputs of various areas as shown in figures below.

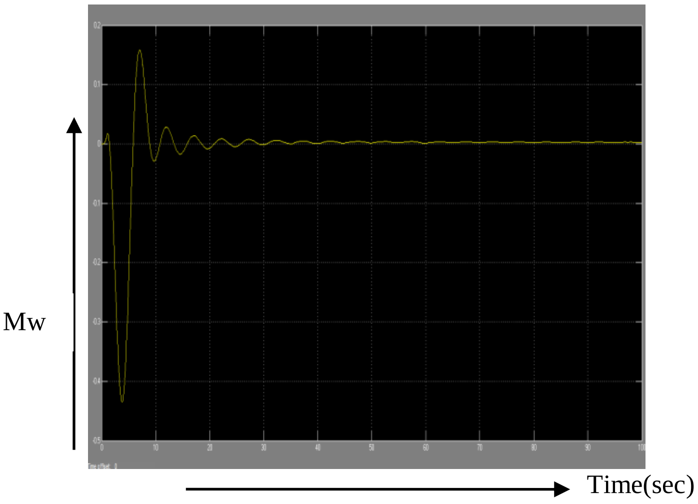

Fig.5: Tie-line power deviations with Fuzzy Logic controller

The power deviations for tie line are shown in Fig.5. The response shows that with the power interchange between the systems the tie line power deviating achieves a steady state at about 35 seconds.

The output response of the system when fuzzy controller is used is shown in figure above. For the power interchange occurring the output of the system under the act of GRC settles down at about 35 seconds with the first overshoot at 0.01Hz and undershoot occurring at 0.075Hz.

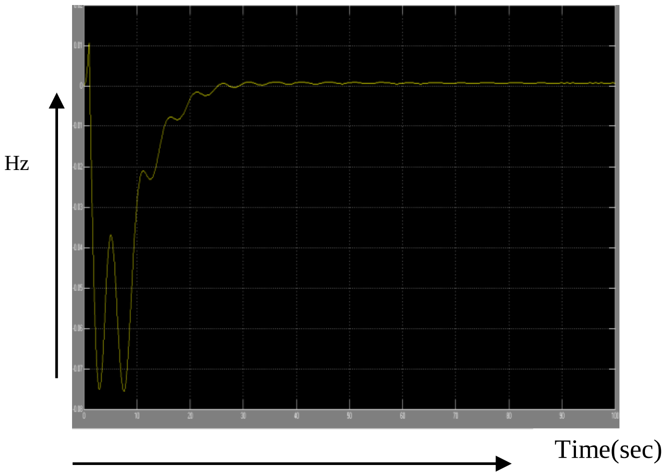

Fig. 6: Frequency deviations in Area-1 with Fuzzy Logic controller

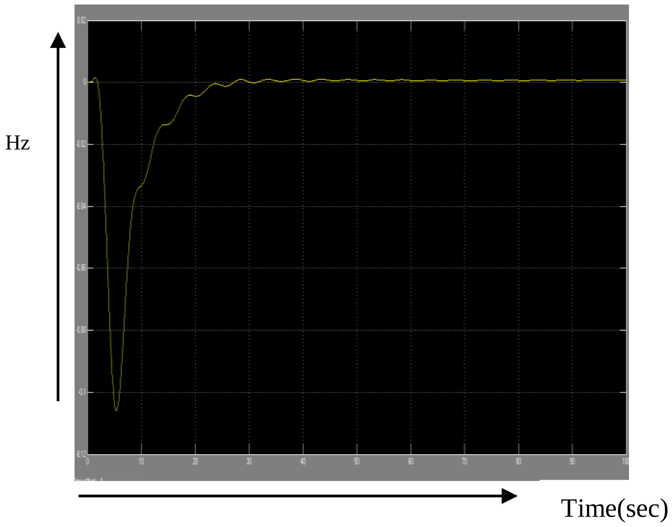

Fig. 7: Frequency deviations in Area-2 with Fuzzy Logic controller

The output response of the system for area 2 when fuzzy controller is used is shown in figure above. For the power interchange occurring the output of the system under the act of GRC settles down at about 35 seconds with the first overshoot at 0.0012Hz and undershoot occurring at 0.1059Hz.

DISCUSSION ON RESULTS

In conventional controllers I(Integral), and PID(Proportional Integral Derivative), PID(Proportional Integral Derivative) controller is better than I(Integral) controller. Because PID controller's over shoot and settling time is much smaller than Integral and Proportional Integral controller. It is observed that the PID controller gives the better results among all the conventional control techniques but when compared with results of Fuzzy controller, it is observed that the Fuzzy Control gives better results than conventional control techniques .The advantage of Fuzzy controller is that it can handle the system non- linearity and at the same time the Fuzzy controller is faster than conventional controllers and gives reduced oscillations and settling time.

VI. CONCLUSION

The different conventional controllers and Fuzzy controller have been implemented for the AGC of two-area power system. It is clear from the results that the performance of PID controller is better than an Integral controller .In case of the PID controller over shoot and settling time is much smaller as compared to Integral controller .The performance of Fuzzy controller has been compared with that of conventional Integral, proportional integral(PI) controller as well as Proportional Integral Derivatives (PID).The Fuzzy controller is faster than conventional controllers and gives reduced oscillations and settling time. This dissertation concludes that the Fuzzy controller is the best out of all the controllers implemented and gives good dynamic performance.

VII. FUTURE SCOPE

The combined use of Fuzzy logic and other intelligent techniques may prove to be better in AGC problems.

VIII. APPENDIX

The nominal system parameters are: f = 50 Hz, Rk = 2.4 Hz / Unit, Tg = 0.08 Sec, Tr = 10.0 Sec, Hk = 5 .0 Sec, Kr= 0.5, Tf = 0.3 Sec, 2πTki = 0.05 Mw, Dk= 0.00833 pu Mw/Hz

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