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Fuzzy Logic Based Automatic Generation Control of Interconnected Power System

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***Abstract**-- This paper proposed Fuzzy Logic Controller (FLC) approach for AGC of two-area interconnected reheat thermal power system with the consideration of Generation Rate Constraint (GRC). The advantage of proposed controller is that it can handle the system non-linearities and at the same time the proposed approach is faster than conventional controllers. The performance of Fuzzy Logic Controller (FLC) has been compared with conventional Integral (I) controller, Proportional integral (PI) and Proportional Integral Derivative (PID) in the presence of Generation Rate Constraint (GRC). System performance is examined considering disturbance in each area of interconnected power system.*

***Keywords**—Automatic Generation Control (AGC), Two-area Power System, Generation Rate Constraint (GRC), Conventional Controllers, Fuzzy Logic Controller (FLC).*

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 value 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).

When area load changes and abnormal fault conditions occurs the system frequency and scheduled power interchange between them is needed to be controlled in order to normalize the system frequency and tie line power interchange, which is required to meet the power demands. For this the Automatic Generation Control (AGC) is one of the essential controls that consider the sudden and small load perturbations. The analysis and design of Automatic Generation Control (AGC) system of individual generator eventually controlling large interconnections 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 AGC problem in interconnected power systems have been reported in the past decades. These investigations dealt with how to select a frequency bias, selection of controller parameters and selection of speed regulator parameter of speed governor. An investigation regarding the AGC of interconnected system is limited to the selection of controller parameter. A number of control schemes have been employed in the design of AGC controllers in order to achieve better dynamic performance. Among the various types of AGC controllers, the most widely used are classical proportional-integral and proportional integral derivative (PID) controller.

Gayadhar Panda, Sidhartha Panda and C Ardil, [1] stated "the main objective of Automatic Generation Control (AGC) is to balance the total system generation against system load losses so that the desired frequency and power interchange with neighboring systems is maintained. Any mismatch between generation and demand causes the system frequency to deviate from its nominal value" Fosha and Elgerd. [2] have used the area controller which operates in response to the integral of the ACE for that area unlike the Classical optimization theory used to find the "best" value of parameters K_I, gain of the area control error (ACE) integrator, and B, frequency bias. G.A.Chown, R.C.Hartman, [3] described the design, implementation and operational performance of a fuzzy controller as part of the Automatic Generation Control (AGC) system.

II. SYSTEM MODEL

An inter-connected power system is considered in the present study. The system comprises of two-area thermal system provided with supplementary controllers. Each area is included with reheat steam turbine with generator rate constraint. A step load perturbation of nominal loading has been considered in area-1and area 2 is observed for various values of speed regulation. The tie line power deviation response following the step load change was also observed. Small perturbation transfer function block diagram of a two-area reheat thermal system is shown in Fig. 1 [1].

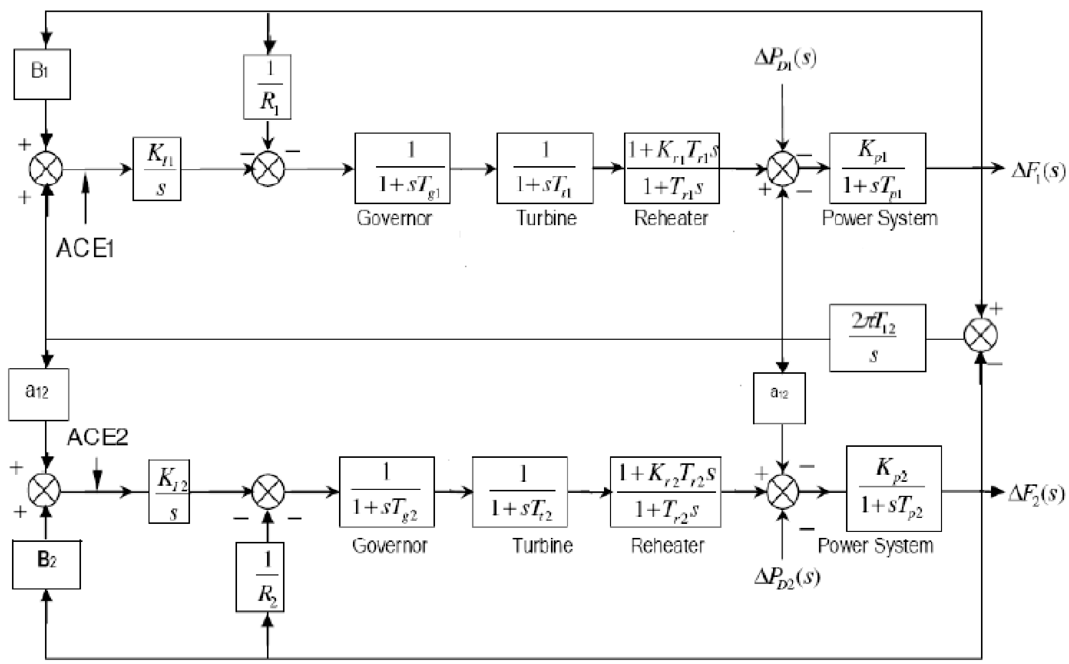

Figure1. Transfer function model of two-area reheat thermal system

The Integral controller improved the relative stability and reduced the steady state error as compared to the system without any use of controller, but increased the oscillations. This led to motivation of using a PID controller which comprises of the best features of I and PI controllers. First the system is simulated with conventional I and PID controller. The control signals from I and PID controller are given in equations below:

For Integral controller the control signal is:

$$U(t)= Ki\int ACE(t)dt \tag{2.1}$$

For PID controller the control signal is:

$$U(t)=KpACE(t)+Ki\int ACE(t)dt+Kd\frac{d(ACE(t))}{dt} \tag{2.2}$$

where *Kp*, *Ki* and *Kd* are the proportional gain, integral gain and the derivative gain of PID controller respectively and ACE(t) is the area control error signal. The conventional controller is then replaced with the proposed fuzzy controller and the dynamic response is observed.

III. CONTROLLER

There are many types of controllers such as proportional, integral, derivative and the combination of these basic controllers, the proportional integral (PI) and the proportional integral derivative (PID) controller.

A. I Controller

The integral control composed of a frequency sensor and an integrator. The frequency sensor measures the frequency error Δf and this error signal is fed into the integrator. The input to the integrator is called the Area Control Error (ACE). The ACE is the change in area frequency, which when used in an integral control loop forces the steady state frequency error to zero. But simultaneously the system response is generally slow and oscillatory.

B. PID Controller

PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode). Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot is for the most part PID type controllers.

C. Fuzzy Logic Controller

Fuzzy logic controller is used for automatic generation control in a two area system. Basic block diagram of fuzzy logic controller is as shown under.

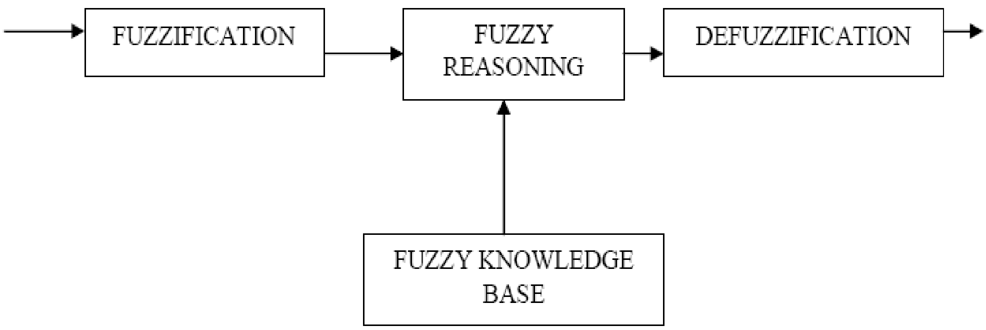

Figure 2 Basic structure of fuzzy logic controller.

The main building units of an FLC are a fuzzification unit, a fuzzy logic reasoning unit, a knowledge base, and a defuzzification unit. Defuzzification is the process of converting inferred fuzzy control actions into a crisp control action. [8]

Design

In the design of an FLC system it is assumed that:

- A solution exists.
- The input and output variables can be observed and measured.

Fuzzy modeling is the method of describing the characteristics of a system using fuzzy inference rules. The method has a distinguishing feature in that it can express linguistically complex nonlinear systems. It is however, very hard to identify the rules and tune the membership functions of the fuzzy reasoning. Fuzzy controllers are normally built with the use of fuzzy riles. These fuzzy rules are obtained either from domain experts or by observing the people who are currently doing the control. The membership functions for the fuzzy sets will be derived from the information available from the domain experts and/or observed control actions. The building of such rules and membership functions require tuning. That is, performance of the controller must be measured and the membership functions and rules adjusted based upon the performance. This process will be time consuming. The basic configuration of Fuzzy Logic Controller (FLC) consists of four main parts.

(i) Fuzzification
(ii) Knowledge base
(iii) Decision-making logic and
(iv) Defuzzificatian

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.

IV. SIMULATION WITH FUZZY LOGIC CONTROLLER

Simulink model of a two area reheated thermal system with Fuzzy Logic Controller is shown in Figure-3. Fuzzy logic is used to calculate ACE (out) i.e. control signal in the form of area control error that will be provided to both the areas to generate according to change in total load to maintain the system frequency within permissible limits. Area control error and change in frequency of the system as input are used as inputs for FLC.

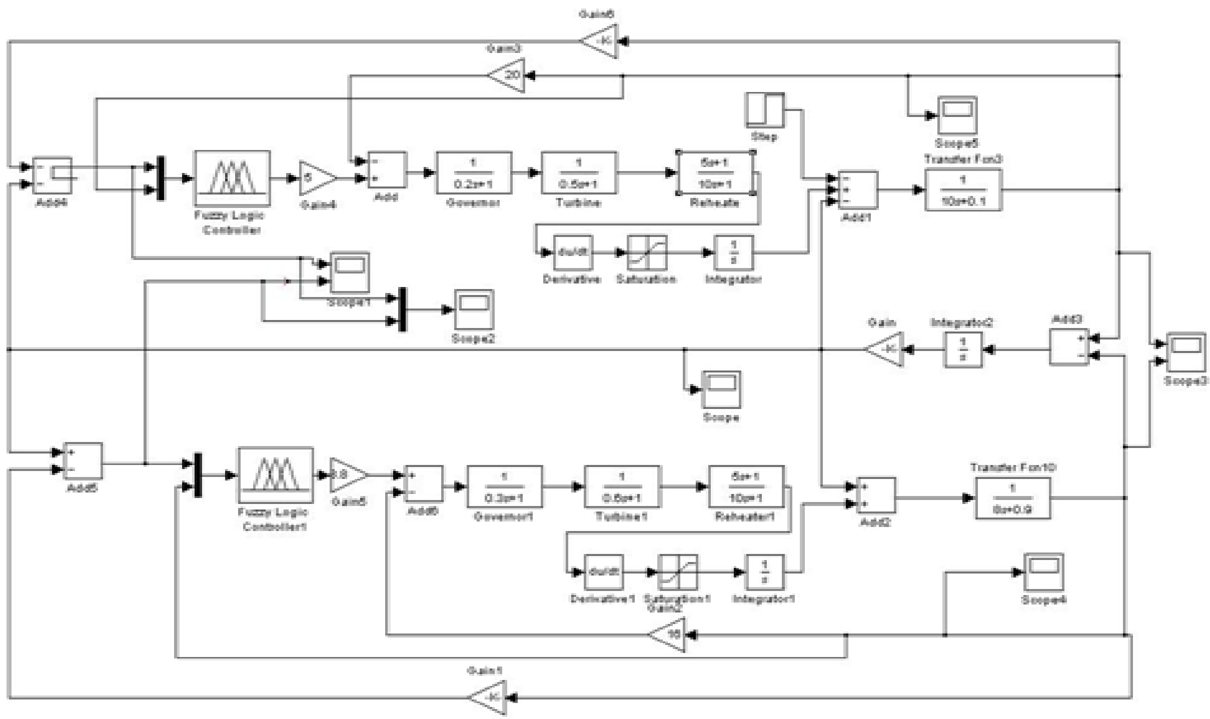

Figure3. Simulink model with Fuzzy Logic controller

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

V. RESULTS

The output Frequency deviation response of tie line, area1 and area2 of two area interconnected thermal reheat power system using fuzzy controller are shown in figure4, figure5 and figure6 respectively and are explained as follows.

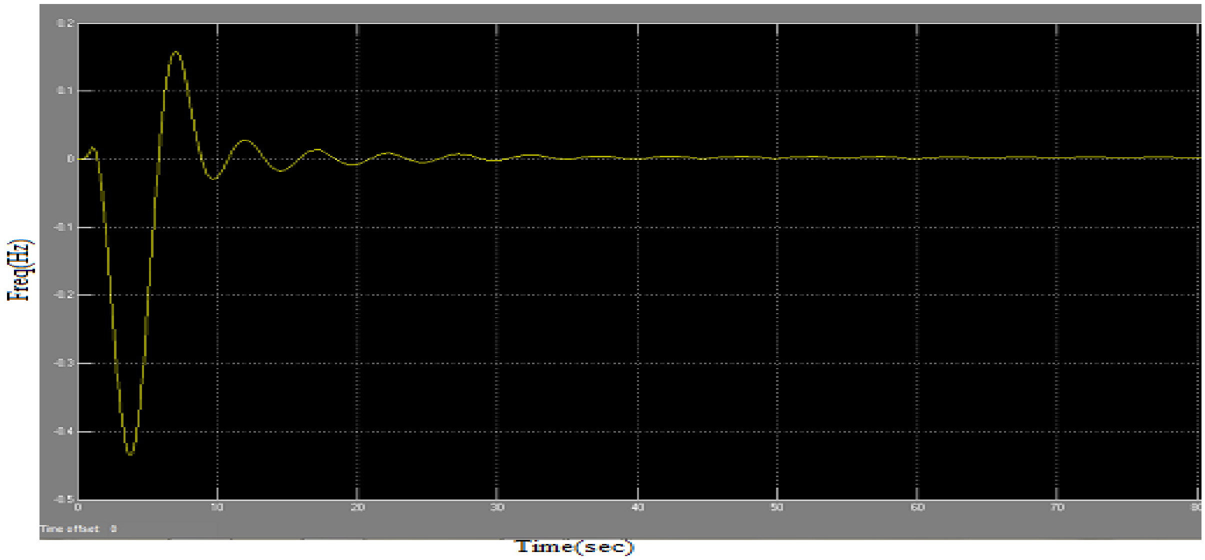

Figure4. Output Tie-line power deviation

The frequency versus time output of the interconnecting tie line is shown in figure 4 above. By using the fuzzy logic controller the first undershoot for tie line occurs at about 3.8 sec approximately with frequency of less than 0.5Hz. Also by using the fuzzy logic controller the settling time of the system reduces to less than 40 sec and thus the system stables out much quickly in response to the load variations occurred.

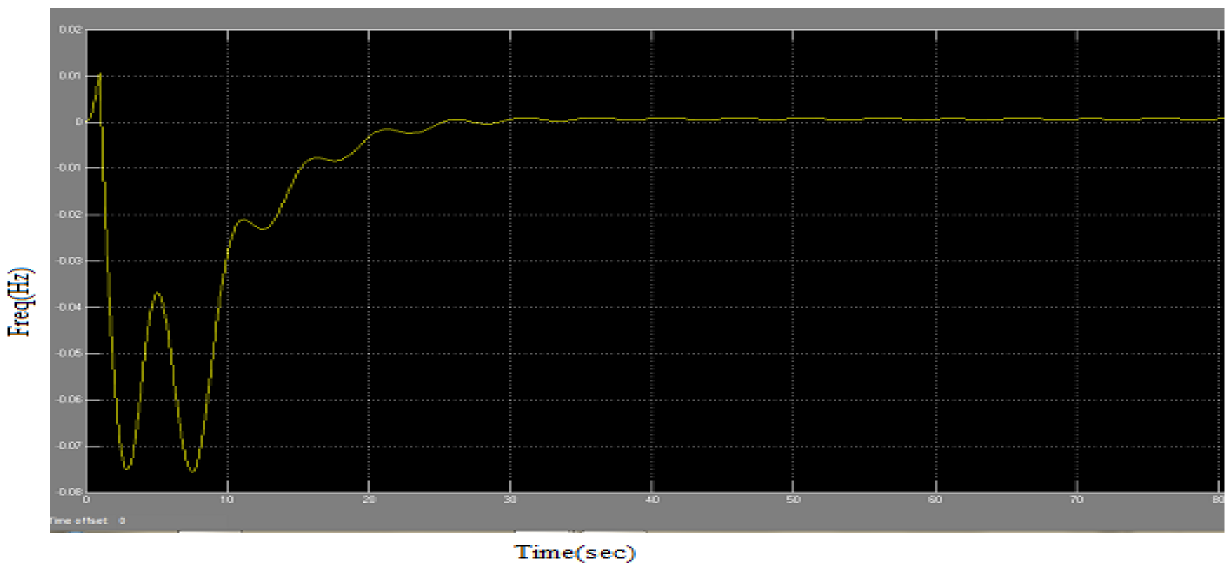

Figure5. Output Frequency deviation in Area-1

Studying out the system's output response with fuzzy logic controller for an interconnected power system figure 5 depicts the output response of frequency deviation of area1. The frequency versus time curve shows that due to the load variations in the system the output of area1 tries to settle down at 40 sec with its overshoot occurring at 0.01Hz and undershoot at 0.075Hz.

Also the output response of the I and PID controllers were obtained and the results were compared and studied with the fuzzy controller output and thus the conclusions were made. The fuzzy controller works faster than the other controllers and gives minimum oscillations and settling time.

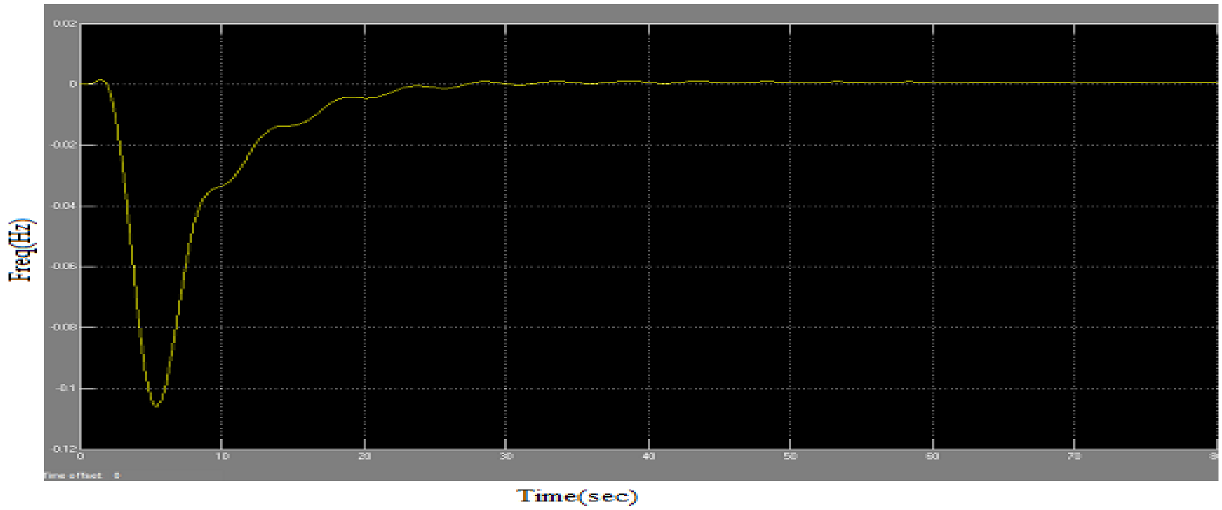

Figure6. Output Frequency deviation in Area-2

Further studying the response of area2 due to load variations that occurred in area1 the output frequency curve of area2 shows that the overshoot occurs at 0.001Hz and the undershoot occurs frequency less than about 0.11 Hz with the settling time of the area2 frequency at about 30sec.

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, 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.

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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