International Journal of Engineering Research and Development (IJERD) ISSN: 2278-067X
Recent trends in Electrical and Electronics & Communication Engineering
(RTEECE 17th – 18th April 2015)

Automatic Generation Control of Two Area using Fuzzy Logic Controller

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Abstract:-*This paper presents the application of Fuzzy logic controller (FLC) for Automatic Generation Control (AGC) of two area thermal power system. Proposed scheme is analyzed considering Generation Rate Constraint (GRC). The dynamic response for 1% load perturbation in system is considered either in any one area, two area or simultaneously in all four areas. The main objective is to improve the frequency deviations of the interconnected system. The performance of fuzzy controller is compared with integral controller. The advantage of fuzzy controller is that it can handle non linearities of the system. The simulation results indicates superiority of fuzzy controller over integral controller and also results are tabulated as a comparative performance in view of settling time and peak under over shoot.*

Keywords:- *Automatic* Generation Control (AGC), Fuzzy logic controller (FLC), Generation Rate Constraint GRC), Area Control Error(ACE)

I. INTRODUCTION

Large scale power systems are normally managed by viewing them as being made up of control areas with interconnections between them. Each control area must meet its own demand and its scheduled interchange power. Any mismatch between the generation and load can be observed by means of a deviation in frequency. This balancing between load and generation can be achieved by using Automatic Generation Control (AGC) [1]. When two or more power system is interconnected, there are several advantages. One is able to sell and buy power with neighboring systems. Further, even if no power is being transmitted, if one system has power loss of a generating unit, in interconnection all units will experience a frequency change and thus can help in restoring frequency. In an interconnected power system Load frequency control (LFC) and automatic voltage regulator (AVR) are installed for each generator. The LFC consist different components which are generator model, load model and prime mover model. The main goal of the LFC is to maintain zero steady state errors for frequency deviation and minimize unscheduled tie-line power flows between neighboring control areas [1,2]. The main objective of AGC is to maintain system frequency at nominal value.

As the size and capacity increases abnormal phenomena have been observed such as the tie line power oscillations under sudden load changes in system. These facts lead to more advanced control techniques. Intelligent controllers have been replacing conventional controllers to get fast and good dynamic response for load frequency. There are different intelligent techniques such as artificial neural network (ANN), fuzzy logic controller (FLC), genetic algorithm (GA), etc. [5]. Implementation of fuzzy logic controller has been carried out on a two non-reheat thermal power system considering the effect of generation rate constraint (GRC). Here two thermal system considering small step load perturbation occurring in a single area as well as in all areas. For the design purpose MATLAB/SIMULINK model of the power system with fuzzy logic controller is developed and the results are compared with the conventional integral controller [3]. A comparative result in table 1 and table 2 shows settling time and peak overshoot.

II. POWER SYSTEM MODEL

The growing concern in power system leads to interconnection of different areas. As the system load changes continuously, the generator is adjusted automatically to restore the frequency to the nominal value. This scheme is known as AGC. Investigations have been carried out on a two equal area non-reheat thermal power system considering the effect of GRC (Fig.). A step load perturbation of 1% of nominal loading has been considered in area-1, area-2 or simultaneously in both two are. With the primary LFC loop a change in the system load will result in frequency deviation. In order to reduce the frequency deviation to zero we must provide a reset action. The reset action is achieved by an integral controller which can change the speed set point in reference to load [1]. For stable operation of power system both constant frequency and constant tie line power exchange should be provided [2]. A control signal made up of tie line flow deviation added to frequency deviation weighted by a bias factor would accomplish the desired objective. This control signal is known as area control error (ACE). ACE serves to indicate when total generation must be raised or lowered in a control area. Area control error (ACE) is the linear combination of frequency and tie line power [2].As the ACE is driven to zero by AGC, both frequency and tie line power errors will be forced to zero [3]. The following equation shows the ACEs for a two area system [2].

(1)
(2)

Where, and are frequency bias factor for area1 and area2 respectively. and are change in frequency for area1 and area2 respectively [2]. and are departures from scheduled interchange. The transfer function block diagram of two area thermal system is as shown in figure 1. The system parameters are given in [3].

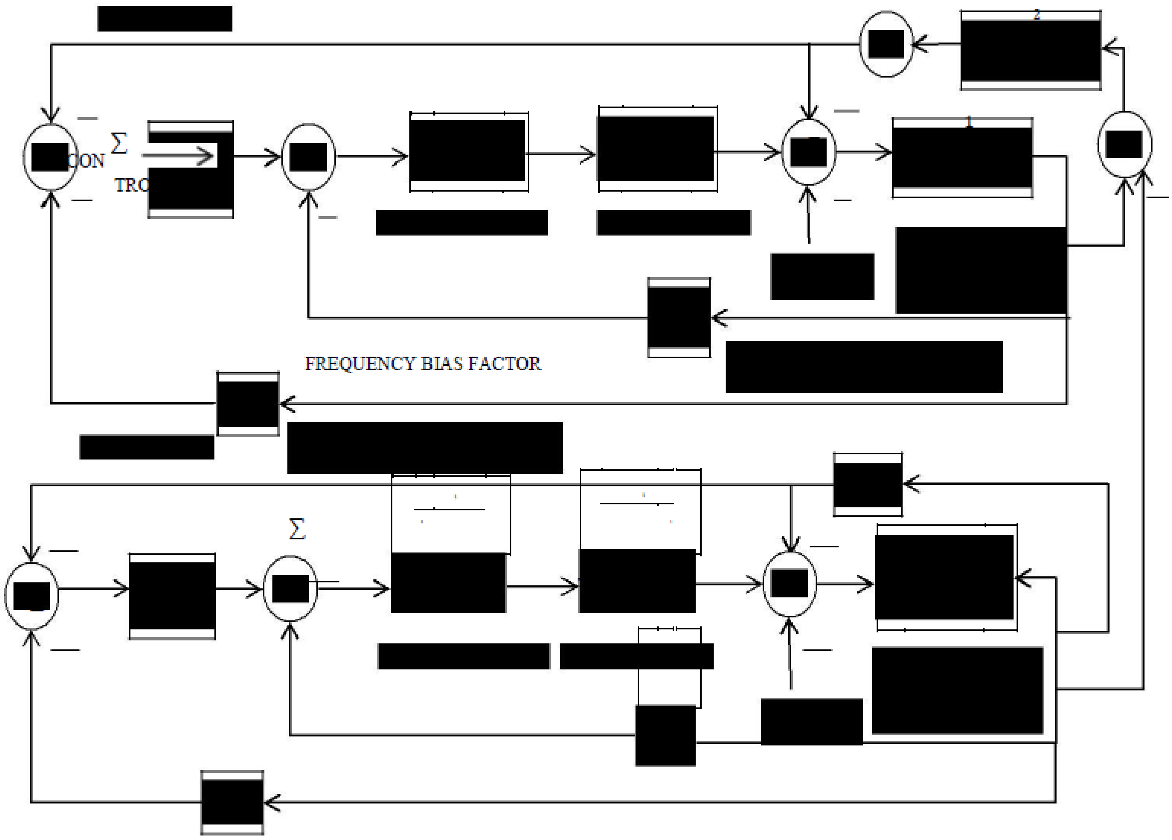

Figure 1: Transfer function model of two area thermal system [1]

A. **GENERATION RATE CONSTRAINT (GRC)**

In power system, power generation can change only at a specified maximum rate and this rate. An important physical constraint is the rate of change of power generation due to the limitation of thermal and mechanical movements, which is known as generation rate constraint (GRC) [3,8]. It is defined as a percentage of the rated output of the control generator per unit of time. A typical value of GRC for thermal unit is 3%/min, i.e. two limiters bounded by ±0.0005 are used within the AGC to prevent the excessive control action i.e., GRC for the k^{th} subsystem is

( )The generation rate constraints for all the areas are taken into account by adding limiters to the turbines as shown in Fig. 1. The GRC results in larger deviations in ACE.

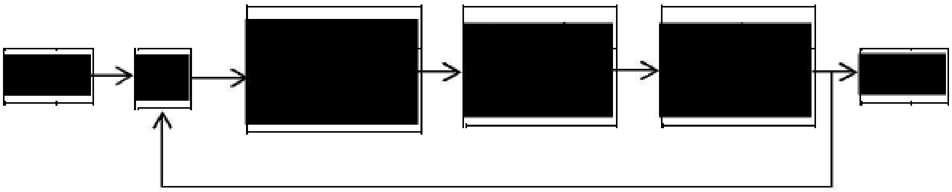

Figure 2: Non-linear turbine model with GRC

III. FUZZY LOGIC CONTROLLER

Fuzzy logic is a thinking process or problem-solving control methodology incorporated in control system engineering, to control systems when inputs are either imprecise or the mathematical models are not present at all. Fuzzification is the process of converting crisp numerical values into the degrees of membership related to the corresponding fuzzy sets. Fuzzification is the conversion of a precise quantity to a fuzzy quantity. If the form of uncertainty happens to arise then the variable is probably fuzzy and can be represented by a membership function. The degree of membership returned by any MF is always in the range [0, 1]. A controller design based on fuzzy logic for a dynamical system involves the following four steps:

1. Define the states and input/output control variables and their variation ranges.
2. Identify appropriate fuzzy sets and membership functions.
3. Construct the fuzzy rule base, using the control rules that the system will operate under.
4. Determine defuzzification method. Combine the rules and defuzzify the output.

In this work Area Control Error (ACE) and derivative of ACE are chosen to be the input signals of fuzzy [3,8,12]. The membership function is a representation of the magnitude of the participation of each member. There are different type of membership function with each type of input and output. In this study, we use the triangular membership function for input and output variable. Five membership functions are used to achieve control using FLC [11]. As the number of linguistic variables increases, both quality improvement in response and computational time are increases. Therefore, a compromise is made to choose the number of variables. Range of input membership function for input one and second input respectively ACE and d(ACE)/dt is form -1 to 1. And range of output is from 0 to 1. Rules determine the conditional state relationship among fuzzy variables. With two inputs each having 5 membership function, we have derived 25 rules. The rules are in the following format.

If error is Ai, and change in error is Bi then output is Ci. Here the “if” part of a rule is called the rule-antecedent and is a description of a process state in terms of a logical combination of atomic fuzzy propositions. The “then” part of the rule is called the rule consequent and is a description of the control output in terms of a logical combination of fuzzy propositions. The output of FLC is a linguistic variable but according to real world requirements, these have to be transformed to crisp value. Defuzzification is used to transform these variables and this process is opposite that of fuzzification. Among various methods Mamdani type of fuzzification method is adopted in the present work.

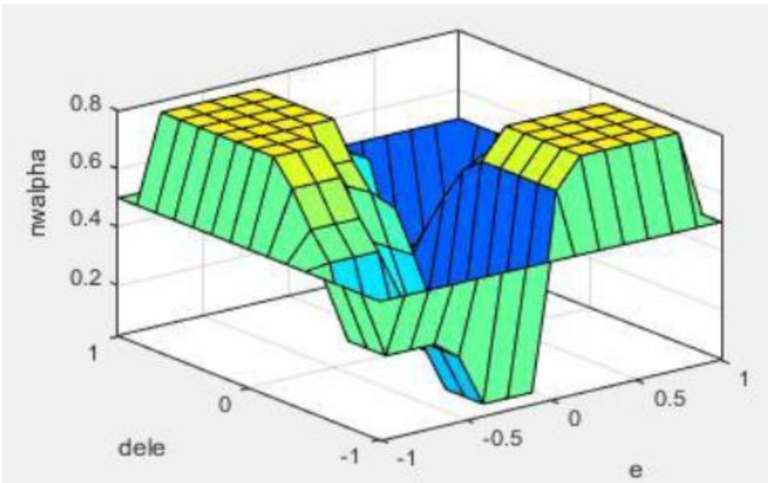

figure 3: Control surface of Fuzzy Controller for AGC

IV. SIMULATION RESULT

In two area system the perturbation can occur either in an area or in both two areas simultaneously. Literature survey shows that 1% load perturbation is considered in an area for optimum results. In our study to assess the effectiveness of the fuzzy logic controller 1% load perturbation is considered in an area and in both area simultaneously. Initially the investigations have been carried out by neglecting Generation Rate Constraint (GRC). Fuzzy Logic Controller with 5 number of triangular Membership function have been used to study on system dynamic response. Results obtained by fuzzy controller are compared with integral controller. And after that the results are observed considering Generation Rate Constraint.

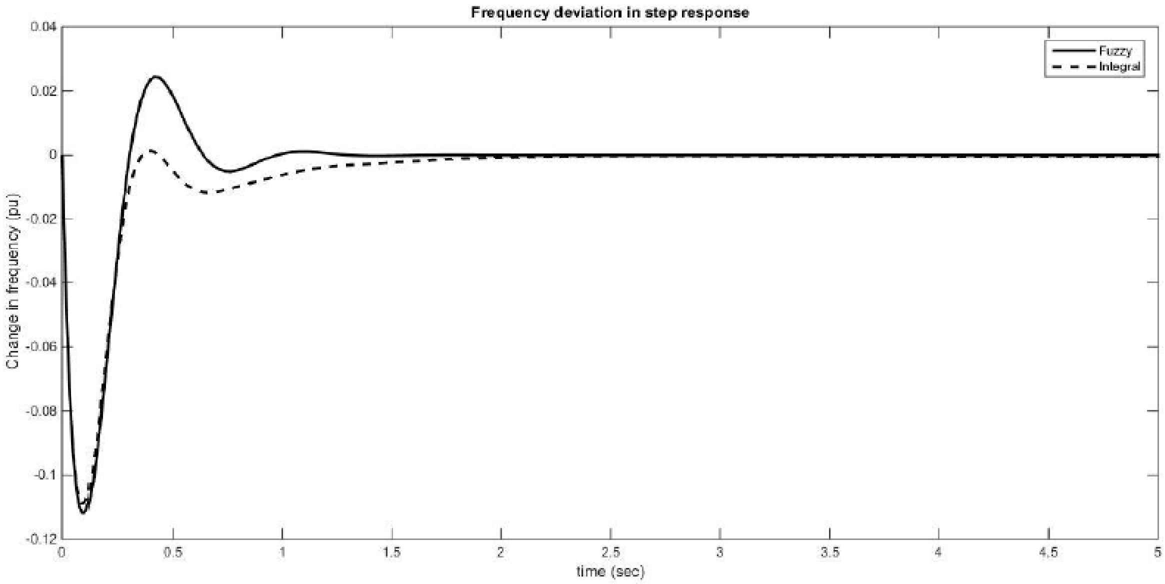

Figure 4: Frequency deviation in area 1 due to disturbance in area 1

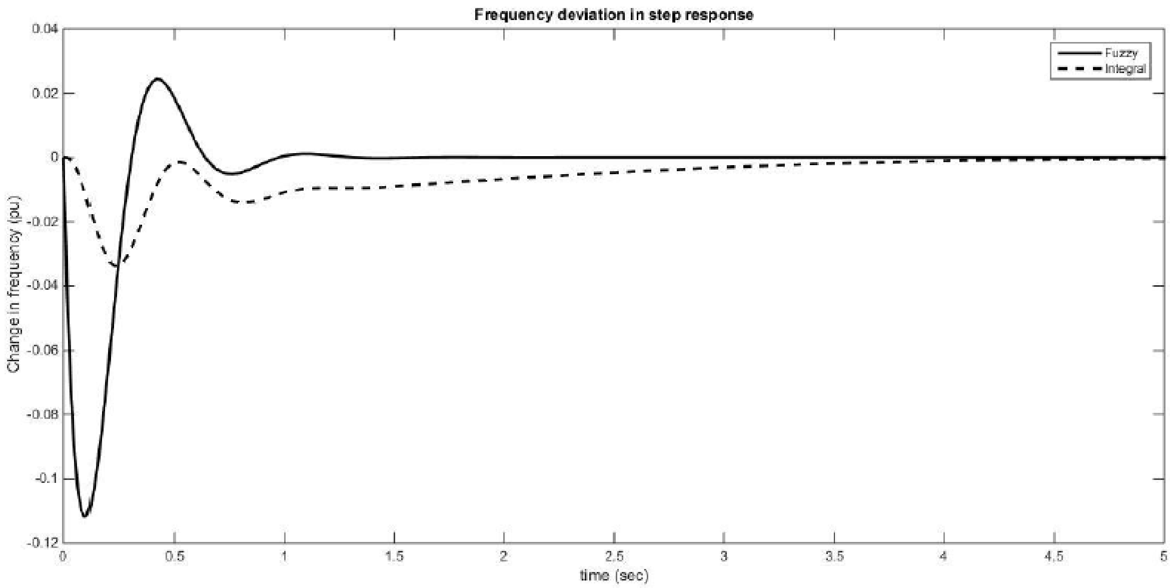

Figure 5: Frequency deviation in area 2 due to disturbance in area 1

Table 1: Time Response Analysis under disturbances in area1

Area	With Fuzzy Controller	With Integral Controller
SETTLING TIME in (Sec)		
For Area 1	1.2	2.2
For Area 2	1.23	4.3
PEAK UNDER OVERSHOOT in (Hz)		
For area1	-0.113	-0.100
For area2	-0.111	-0.034

Figure 4 and figure 5 shows the simulation result of fuzzy logic in comparison with integral controller without considering Generation rate constraint with disturbance in area 1. Continuous line shows fuzzy logic output and dotted line shows output with integral controller. Table 1 gives the time response analysis of two area system with fuzzy controller and with integral controller.

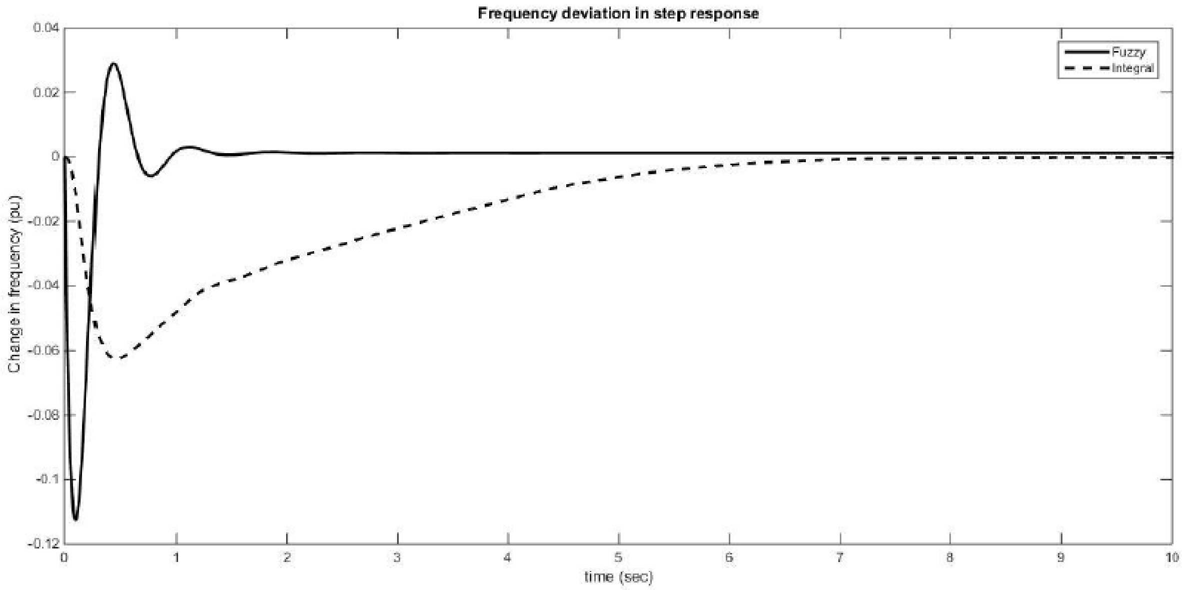

Figure 6: Frequency deviation in area 1 due to disturbance in area 2 with GRC

Figure 6 and figure 7 shows the simulation result of fuzzy logic in comparison with integral controller considering Generation rate constraint with disturbance in area 2. Continuous line shows fuzzy logic output and dotted line shows output with integral controller. Table 2 gives the time response analysis of two area system with fuzzy controller and with integral controller considering generation rate constraint.

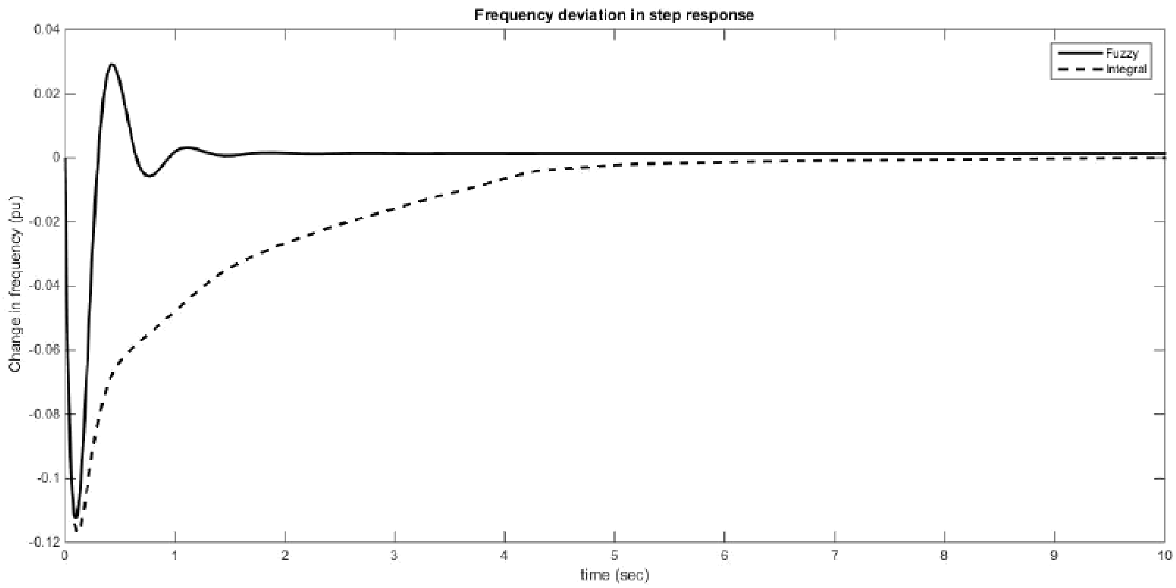

Figure 7: Frequency deviation in area 2 due to disturbance in area 2 with GRC

Table 2: Time Response Analysis under disturbances in area2 with GRC

Area	With Fuzzy Controller	With Integral Controller
SETTLING TIME in (Sec)		
For Area 1	1.21	8.2
For Area 2	1.33	9.1
PEAK UNDER OVERSHOOT in (Hz)		
For area1	-0.11	-0.06
For area2	-0.112	-0.096

V. CONCLUSION

This study is an application of fuzzy logic controller to automatic generation controller of a two area thermal system. In this work simulation is done with fuzzy logic controller and conventional integral controller with generation rate constraint. The conventional integral controller has its limitation in handling non-linearities and being slow. The settling time for integral controller is much more than the fuzzy controller. Proposed Fuzzy Logic Controller is more accurate and faster and also it gives better results even when Generation Rate Constraint is considered. The superiority of fuzzy controller is investigated from simulation results for all types of perturbation. It is observed that fuzzy controller is more suitable when complexity of power system is increasing day by day. Design of fuzzy controller is simple as it works on linguistic variables and does not required system mathematics and also it is efficient.

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