A Two Area Load Frequency Control Using Fuzzy Gain Scheduling of Pid Controllers

Miss. Ingle Sneha M.[1], Dr. B.M. Patil[2]
[1, 2] Dept of Control System
[1, 2] College Of Engineering Ambajogai

Abstract- *Continuous load perturbation in power systems network affects the frequency directly. If the system load frequency control (LFC) mechanism is working perfectly, the frequency is quickly returned to the normal operating point. The conventional controllers such as PI, PID have been employed for the LFC, but these controllers are slow and do not allow the controller designer to take into account possible changes in operating conditions and nonlinearities in the generator unit. To overcome these drawbacks a new intelligent controller such as fuzzy controller is presented in this thesis to quench the deviations in the frequency and the tie line power due to different load disturbances. The fuzzy logic controller which is based on human expertise knowledge is employed to overcome all the setbacks witnessed in all the other controllers. Fuzzy Logic has the features of simple concept, easy implementation, and computationally efficient. Simulation results for a real two-area power system prove the effectiveness of the proposed LFC and show its superiority over a classical PID controller. The result shows an improved performance in terms of rise time, settling time, steady state error and overshoot.*

Keywords- Automatic generation control (AGC), load frequency control (LFC), Fuzzy logic controller (FLC), Proportional-Integral- Derivative controller (PID Controller), Extra High Voltage Alternating Current (EHVAC).

I. INTRODUCTION

Modern power systems are interconnected units in which the electrical power is transferred between them. Automatic generation control (AGC) play a great role in power system to preserve frequency and transferred power in their scheduled value in normal condition and in case of deviation of the load. The initial aim of AGC is frequency regulation to nominal value and preserving power transfer between the control areas by changing output of selected generators. This is called load frequency control. The second aim is to reduce the operation cost by distributing the needed change between generations of the units [1],[2]. Generally AGC is a control system with three main objects as mentioned below:

- Preserving system frequency in its nominal value or a value close to it.
- Preserving correct value of power transfer between areas.
- Preserving each unit generation in an economically suitable value [1], [3]

When the load increases, the turbines velocity will decrease until the governor could coordinate the incoming steam with the new load. The less changes of the velocity will result in less error. Since the power system load change is continuous, generation control is set to automatic state to restore nominal values of frequency [4],[5].

The load frequency control (LFC) of a multi-area power system is the mechanism that balances between power generation and the demand regardless of the load fluctuations to maintain the frequency deviations within acceptable limits. The basic means of controlling prime- mover power to match variations in system load is through control of the load reference set-points of selected generating units. The main purpose of designing load-frequency controllers is to ensure the stable and reliable operation of power systems. Since the components of a power system are non linear, a linearized model around an operating point is used in the design process of L-F controllers. Some of the proposed methods in literature deal with system stability using fixed local plant models ignoring the changes on some system parameters [6],[7].

II. MODELING OF TWO-AREA POWER SYSTEM

A two area system consists of two single area systems, connected through a power line called tie-line. Each area feeds its user pool, and the tie line allows electric power to flow between the areas. Information about the local area is found in the tie line power fluctuations. Therefore, the tie-line power is sensed, and the resulting tie-line power is fed back into both areas.

It is conveniently assumed that each control area can be represented by an equivalent turbine, generator and governor system. Each power area has a number of generators which are closely coupled together so as to form a coherent group, i.e., all the generators respond in unison to changes in the load. Now we will see the dynamics of power system.

The automatic load frequency control loop is mainly associated with the large size generators. The main aim of the automatic load frequency control (ALFC) can be to maintain the desired unvarying frequency, so as to divide loads among generators in addition to managing the exchange of tie line power in accordance to the scheduled value. Various components of the automatic load frequency control loop are as given away in the Figure.2.1.

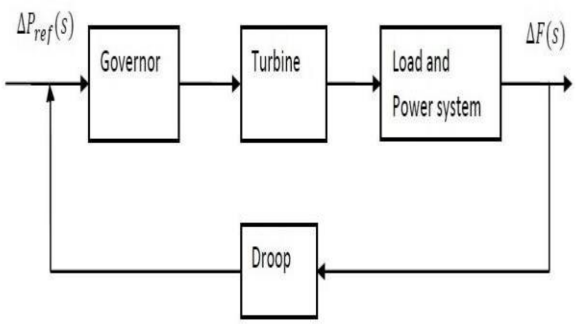

Figure 2.1: Block diagram of automatic load frequency control

MATHEMATICAL MODELING

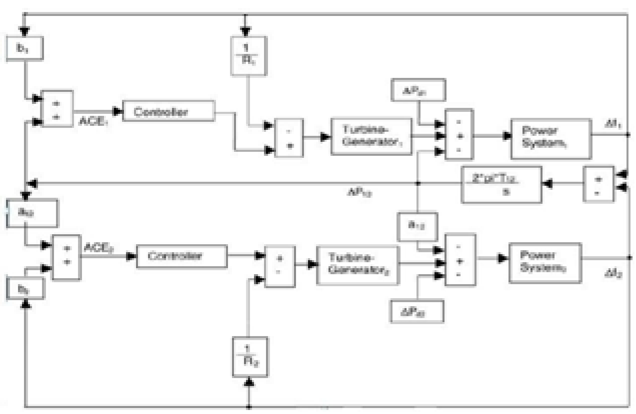

Figure 2.2: Block diagram of two-area power system

Figure.2.2 shows the two area power system. The different components of this power system are turbines, generators, governors ,load and tie-line. Here the mathematical modelling for each of these parts is given.

III. FUZZY LOGIC CONTROLLER

General fuzzy logic controller and its design for our two area power system is seen. Fuzzy logic is originated as logic of ambiguous concepts. The method of fuzzification has found increasing applications in power systems. The applications of fuzzy sets signify a major enhancement of power system analysis by avoiding heuristic assumptions in practical cases. This is because fuzzy sets could be deployed properly to represent power system uncertainties.

The design of Fuzzy Logic Controller (FLC), however, can be divided into three stages: fuzzification, rule base and defuzzification. In the model of fuzzy system, there are two types of model available: Mamdani and Sugeno type model. Mamdani type of model is used in this thesis because of its feasibility in implementation.

The process of converting crisp value into fuzzy value is known as fuzzification. In this process mem- bership functions are used. Membership functions are further used as linguistic variables. Knowledge base contains knowledge about all input and output fuzzy partition. Rule base is also known as knowledge base. Fuzzy control rules are also available in knowledge base. All fuzzy rules are written by using previous knowledge about the system. Fuzzy rules are usually written in implication form, that is, IF-THEN format. For example,

“IF x is A THEN y is B”.

Finally, the method of converting fuzzy value into crisp value is called defuzzification. In the literature many types of defuzzifications are reported. Then, this converted crisp value is used to control the system.

DESIGN OF FL CONTROLLER

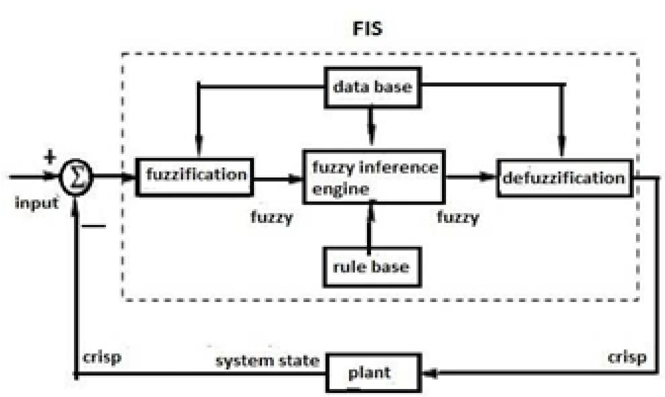

Figure 3.1: Structure of fuzzy logic controller [22]

The Figure 3.1 shows the basic structure of fuzzy logic controller. The FL controller design processes involves selection of suitable membership function, correct rule base design and proper defuzzification method. The following sections deal the same.

Fuzzification

Fuzzification is the first step to apply a fuzzy inference system. It needs to convert those crisp variables (both input and output) to fuzzy variables, and then apply fuzzy inference to process those data to obtain the desired output. Finally, in most cases, those fuzzy outputs need to be converted back to crisp variables to complete the desired control objectives. Generally, fuzzification involves two processes: derive the membership functions for input and output variables and represent them with linguistic variables.

Defuzzification

Defuzzification is the conversion of fuzzy quantity into crisp quantity. The output of a fuzzy process can be the logical union of two or more fuzzy membership functions defined in the universe of discourse of the output variable. In the literature many defuzzification methods have been proposed, but only four methods have titled:

1. Max membership method
2. Weighted average method
3. Mean max membership method and
4. Centroid method.

Max membership or height method is based on the peak value of the output. Weighted average method is termed by weighting each membership function in the output by its respective maximum membership value. Mean max defuzzification method works on mean value of peak membership. On the other hand, centroid method also known as centre of area or centre of gravity method is the most prevalent defuzzifi- cation methods. In this thesis centroid method is used for defuzzification.

Centroid Method

Centroid method is also known as centre of gravity method, it obtains the centre of area z^*occupied by the fuzzy set A of universe of discourse Z. It is given by the expression

$$z^* = \frac{\int_z \mu_A(z) z dz}{\int_z \mu_A(z) dz}$$

for a continuous membership function,and

$$z^* = \frac{\sum_{i=1}^{n} z_i \mu_{(}z_i)}{\sum_{i=1}^{n} \mu_{(}z_i)}$$

for a discrete membership function.
where μA(z) is the aggregated output MF.
This is the most widely used adopted defuzzification strategy, which is reminiscent of the calculation of expected values of probability distributions.

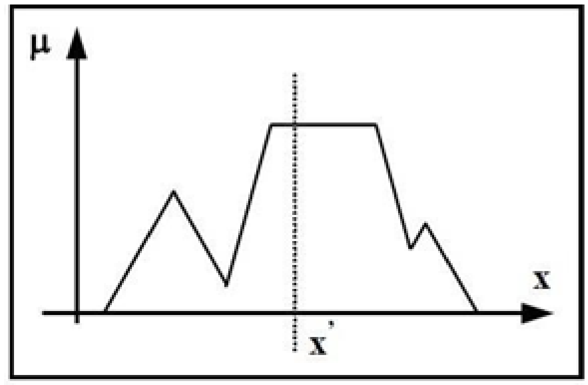

Figure 3.2: COG method [23]

IV. RESULTS AND DISCUSSIONS

There is a basic fuzzy logic controller with its rule base,different implication meth- ods,fuzzification and difuzzification and its implementation for two-area power system is given. In this chapter there is simulation of two-area power system with different controllers and then the simulation results are compared. Before going to simulation results let's see the design model for various systems:

DESIGN MODEL FOR VARIOUS SYSTEMS

Single Area System

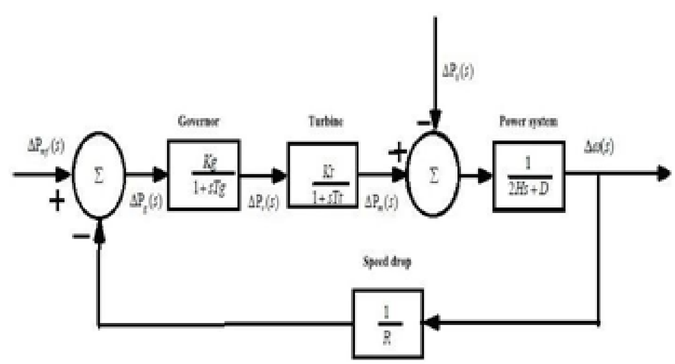

Figure 4.1: Model of single area ALFC without using secondary control

Figure.4.1 shows the Automatic Load Frequency Control (ALFC) loop. The frequency which changes with load is contrasted with reference speed setting. The frequency can be set to the desired value by making generation and demand equal with the help of steam valve controller which regulate steam valve and increases power output from generators. It serves the primary/basic purpose of balancing the real power by regulating turbine output (ΔPm) according to the variation in load demand ($\Delta P0$).The transfer function of the model of the single area system as shown in Figure.4.1 is as below

$$\Delta\omega(s) = -\Delta P0(s)T(s) \qquad (4.3)$$

For the case with load which is not sensitive to frequency load (D = 0):

$$\Delta\omega ss = (-\Delta P0)R \qquad (4.4)$$

From the above equations we can get the steady state value of new system frequency which is less than the initial value. But we have to make the frequency drift ($\Delta\omega$) to zero or to an acceptable value with the help of secondary loop for stable operation. This is shown above.Due to change in load there is change in the steady state frequency ($\Delta\omega$) so we need another loop apart from primary loop to convey the frequency to the initial value, before the load disturbance occurs. The integral controller which is responsible in making the frequency deviation zero is put in the secondary loop as shown in Figure.4.2.

Therefore the signal from $\Delta\omega(s)$ is being fed back all the way through an integrator block (1/s) to regulate ΔPre f to get the frequency value to steady state. Thus $\Delta\omega(s) = 0$. Thus integral action is responsible for automatic adjustment of
ΔPre f making $\Delta\omega = 0$. So this act is known as Automatic Load Frequency Control transfer function with integral group is shown below by representing it in the form of equation:

$$\omega = \frac{1}{D + \frac{1}{R}}[\Delta P_{ref} - \Delta P_0] \qquad (4.4)$$

V. SIMULATION RESULTS

In order to show the effectiveness of proposed controller a two-area power system is to be simulated in MATLAB/SIMULINK and the simulation results are compared with that of the open loop response and PID controller. The simulation for open loop response is as shown below:

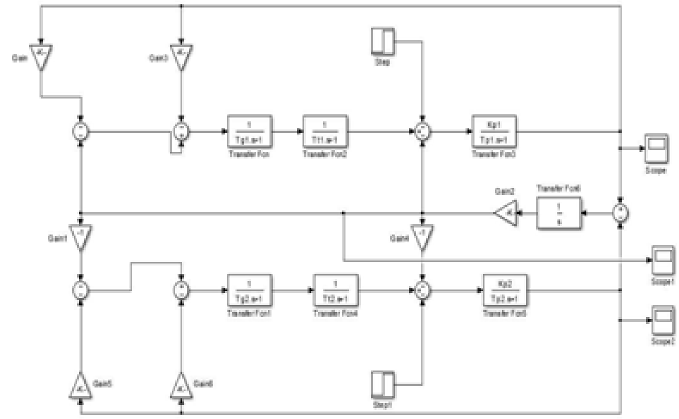

Figure 5.1: Simulation diagram for open loop response

The PID controller improves the transient response so as to reduce error amplitude with each oscillation and then output is eventually settled to a final desired value. Better margin of stability is ensured with PID controllers. The mathematical equation for the PID controller is given as [25] and [26].

$$y(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{d}{dt}e(t) \qquad (5.1)$$

Where y (t) is the controller output and u (t) is the error signal. Kp, Ki and Kd are proportional, integral and derivative gains of the controller. The limitation conventional PI and PID controllers are slow and lack of efficiency in handling system non-linearity.

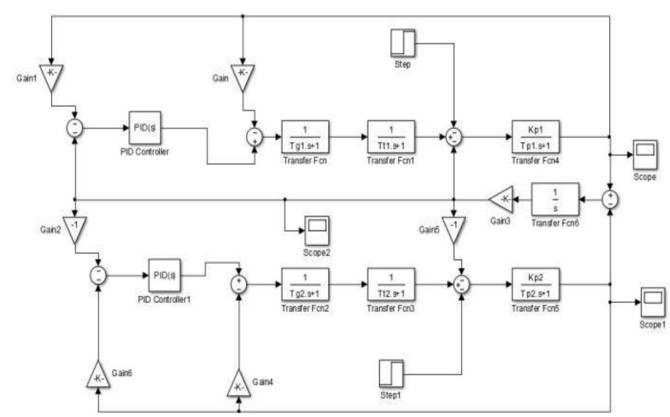

Figure 5.2: Simulation diagram using PID controller

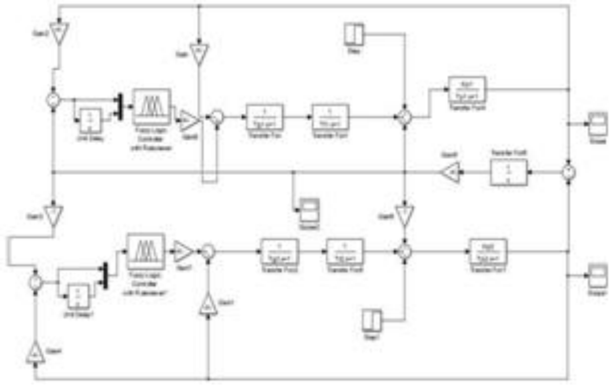

Figure 5.3: Simulation diagram using fuzzy logic Controller

The combined results for frequency deviations in different areas and dynamics for tie-line power varia- tions with different controllers is as shown below:

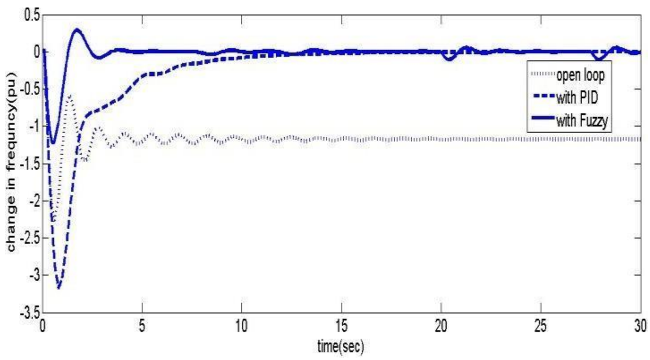

Figure 5.4: Dynamic responses for frequency deviation of area 1

The following chart shows the comparison between the results obtained with Fuzzy and PID controllers:

From the above result it is clear that with open loop the peak overshoot is high and it is 0.5, whereas with PID controller it is zero and with Fuzzy logic controller it is reduced to 0.2 for area 1. In open loop system the graph never settles down, for PID controller the settling time is 15 sec and for Fuzzy logic controller it is 4 sec. The steady state error in open loop system is 1.2 and it is completely eliminated in case of PID and Fuzzy logic controller.

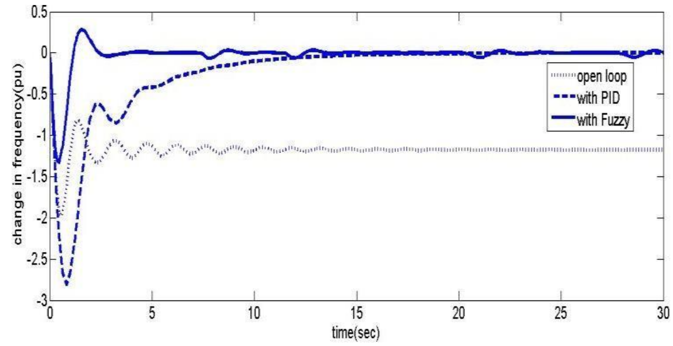

Figure 5.5: Dynamic responses for frequency deviation of area 2

From the above result it is clear that with open loop the peak overshoot is high and it is 0.4, whereas with PID controller it is zero and with Fuzzy logic controller it is reduced to 0.3 for area 2.

In open loop system the graph never settles down, with PID controller it settles at 17 sec and with Fuzzy logic controller.It settles at 6 sec. The steady state error in open loop system is 1.3 and it is completely eliminated in case of PID and Fuzzy logic controller.

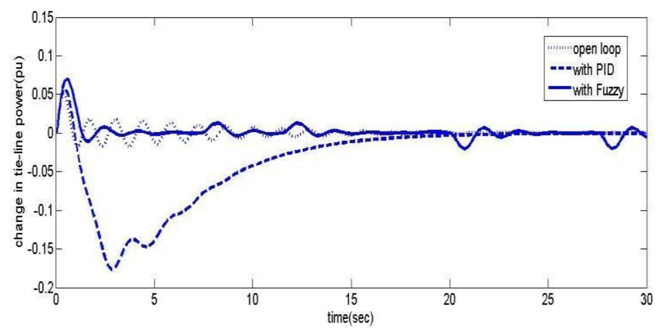

Figure 5.6: Dynamic responses for frequency deviation of tie-line between area 1 and area 2

From the graph 5.6: It is clear that the steady state error is almost eliminated using fuzzy logic controller. The settling time is 17 sec for Fuzzy logic controller, 20 sec for PID controller, whereas it never settles down with open loop.

VI. CONCLUSIONS AND FUTURE SCOPE

CONCLUSIONS

The present dissertation is mainly focused on technical issues associated with the load-frequency con- trol (LFC) in restructured power systems and addresses new generalized dynamic models for the inter- connected electric power systems with possible structures in a competitive environment. In this paper a fuzzy logic controller is designed for load frequency controller of two area interconnected power system. It can be implemented in four area power system and controlled by using advanced controller systems. The system performance is observed on the basis of dynamic parameters i.e., settling time, overshoot, undershoot and steady state error. By using these controllers, the steady state error, settling time and peak- overshoot are reduced. The system performance characteristics reveal that the performance of fuzzy logic controller is better than the PID controller. As a further study the proposed method can be applied to multi area power system load frequency control (ALFC) and also optimum values can be obtained by Genetic Algorithm and Neural networks.

FUTURE SCOPE

In this dissertation, we apply S MC to a continuous, two area, three area interconnected power system with three different kinds of turbines. The nonlinearities such as GDB and GRC are included in the block diagram model of the power system. The mathematical model of the linear parts of the power system is constructed. Our control goal is to drive the ACE to zero. In this dissertation, the S MC is originally simulated on the three-area interconnected power system with nonlinearities. First, we test the SMC on one-area and two-area power systems. Then, the SMC is tested on a three-area interconnected power system under different load disturbances. The simulation results show that frequency error, tie- line power error, and ACE are driven to zero successfully under different load disturbances. Other intelligent techniques such as Artificial Neural Network, Adaptive Fuzzy logic controller (AFLC), PS O based algorithm are used for the load frequency control of multi area power system. AFLC schemes are classified as direct and indirect [27]. In the direct adaptive fuzzy logic control (DAFLC), a fuzzy logic system is used to generate the control signal whereas in the indirect adaptive fuzzy logic control (IAFLC), a fuzzy logic system is used to approximate unknown functions of the plant. A direct indirect adaptive fuzzy logic LFC is proposed where fuzzy logic systems are employed for each area to construct the primary control part and to approximate the unknown interconnection terms and the unknown nonlinearities due to GDB and GRC. The controller parameters are updated to reduce the error between the subsystem output and a given reference signal.

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