Dynamic Response Analysis through Conventional Methods and Fuzzy Logic for Automatic Load Frequency Control

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ABSTRACT : *A Load Frequency Control is important in electrical power system design and operation. Due to unexpected large power consumption in industries and other sectors, power deficiency fulfillment is great task to be accomplished for the generation side. So to make counter balance for generation and expected demand, Load frequency control is used. For the reliable operation of a large interconnected power system an automatic generation control (AGC) is required; its main role is to maintain the system frequency and to maintain the tie line flow at their scheduled values during normal period in an interconnected system. The output from conventional methods i.e. performance of the controllers like PI, PID (proportional, integral and derivative and their combination) are studied and compared among different aspects and at the most Fuzzy Logic is proposed to for power system because the limitations of the Conventional controls possess deficiency to optimal value as requisite and variation in load and frequency analysis point of view while handling non-linearity in system. The fuzzy logic controllers found to be better one and it provides almost appropriate dynamic responses over the conventional PI, PID controller. System simulation is realized through numerous matlab-Simulations.*

Keywords: *Load frequency control, Automatic generation control, Proportional-integral-derivative controller, two area power system*

I. INTRODUCTION

In an electric power system, automatic generation control is a system for adjusting the power output of multiple generators at different power plants, in response to changes in the load. Since a power grid requires that generation and load closely balance moment by moment, frequent adjustments to the output of generators are necessary. The balance can be judged by measuring the system frequency; if it is increasing, more power is being generated than used, and all the machines in the system are accelerating. If the system frequency is decreasing, more loads are on the system than the instantaneous generation can provide, and all generators are slowing down.

Before the use of automatic generation control, one generating unit in a system would be designated as the regulating unit and would be manually adjusted to control the balance between generation and load to maintain system frequency at the desired value. The remaining units would be controlled with speed droop to proportion their share of the load according to their ratings. With automatic systems, many units in a system can participate in regulation, reducing wear on a single unit's controls and improving overall system efficiency, stability, and economy.

The main objectives of Automatic Generation Control (AGC) are:

(i) To maintain the desired megawatt output and the nominal frequency in an interconnected power system

(ii) To maintain the net interchange of power between control areas at predetermined values.

I.I LOAD FREQUENCY CONTROL

For satisfactory operation of a power system, the frequency should remain nearly constant. This is the reason why system frequency must not be allowed to deviate from a chosen constant value. Most types of ac motors run at speeds that are directly related to the frequency. The generator turbines, particularly steam driven ones, are designed to operate at a very precise speed. The overall operation of a power system can be much better controlled if the frequency error is kept within strict limits. A large number of electrically operated clocks are used. They are all driven by synchronous motor, and the accuracy of these clocks is a function not only of the frequency error but actually of the integral of this error.

The frequency of a system is dependent on active power balance. As frequency is a common factor throughout the system, a change in active power demand at one point is reflected throughout the system by a change in frequency. Because there are many generators supplying power into the system, some means must be provided to allocate change in demand to the generators. A speed governor on each generating unit provides the primary speed control function, while supplementary control originating at a central control Centre allocates generation.

In an interconnected system with two or more independently controlled areas, in addition to control of frequency, the generation within each area has to be controlled so as to maintain scheduled power interchange. The control of generation and frequency is commonly referred to as load frequency control (LFC).

The Generation control is big issue as ever increasing demand of power. So every possible improvement in this area helps in favor of power demand. The main purpose of Automatic generation control is to maintain the frequency steady at its nominal value. Since the industrial revolution man's demand for and consumption of energy has increased steadily. The invention of the induction motor by Nikola Tesla in 1888 signaled the growing importance of electrical energy in the industrial world as well as its use for artificial lighting. A major portion of the energy needs of a modern society is supplied in the form of electrical energy.

Industrially developed societies need an ever-increasing supply of electrical power. Very complex power systems have been built to satisfy this increasing demand. To follow the increasing demand of power the generated power control should be maintained.

I.II BASIC BLOCK DIAGRAM

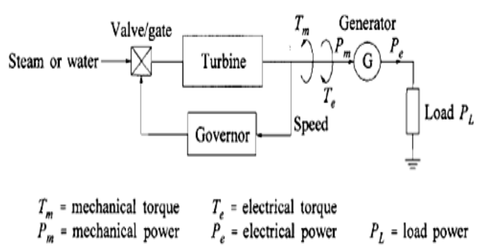

Fig. 1 Block Diagram of Load frequency controllers [6]

II. IMPLEMENTATION OF TWO AREAS LOAD FREQUENCY CONTROL

To form the basis for supplementary control of interconnected power systems, Let us first look at the performance with primary Speed Control only.

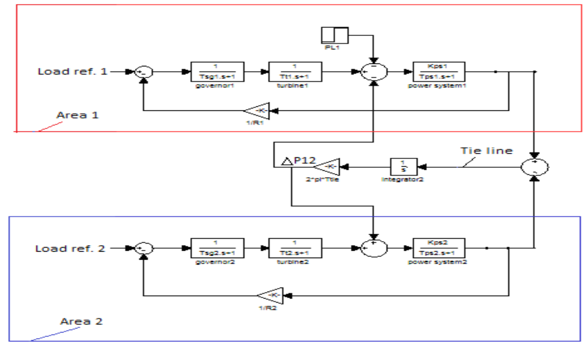

Fig. 2 Block diagram of Two-area system with only primary speed control

The block diagram representation of the system is shown in figure 2 with each area represented by an equivalent power system gain Kps, time constant Tps, Turbine and governing system with an effective speed droop R. The tie line is represented by the synchronizing torque coefficient T. A positive ΔP_{12} represents an increase in power transfer from area 1 to area 2. This in effect is equivalent to increasing the load of area 1 and decreasing the load of area 2; therefore, feedback of ΔP_{12} has a negative sign for area 1 and a positive sign for area 2.

The steady-state frequency deviation ($f - f_0$) is same for the Two-areas as shown in figure 3. For a total load change of ΔP_L,

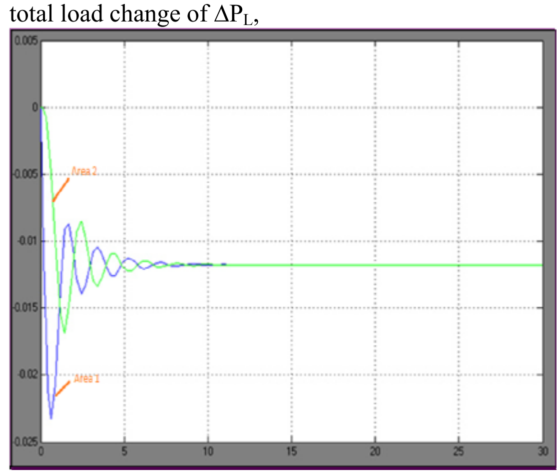

Fig. 3 Steady state Frequency deviations for Two-area system due to Primary Control

FREQUENCY BIAS TIE LINE CONTROL

The basic objective of supplementary control is to restore balance between each area load and generation. This is met when the control action maintains Frequency at the scheduled value and

Net interchange power with neighboring areas at scheduled values.

The supplementary control in a given area should ideally correct only for changes in that area. In other words, if there is a change in area 1 load, there should be supplementary control action only in area 1 and area 2.

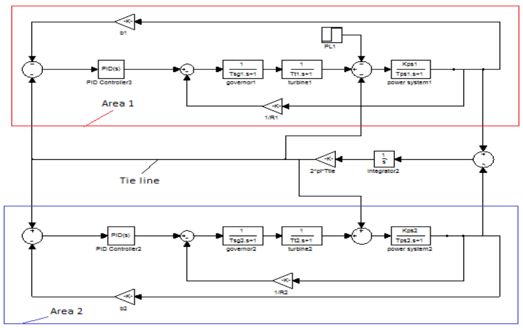

Fig. 4 block diagram of Two-area system with supplementary control

The figure 4 shows that how supplementary control is implemented. It is applied to selected units in each area and acts on the load reference set-points.

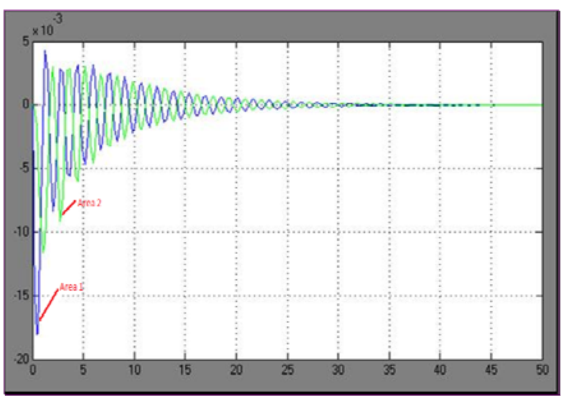

Fig. 5 Frequency steady at its nominal value due to secondary control loop using PI Controller

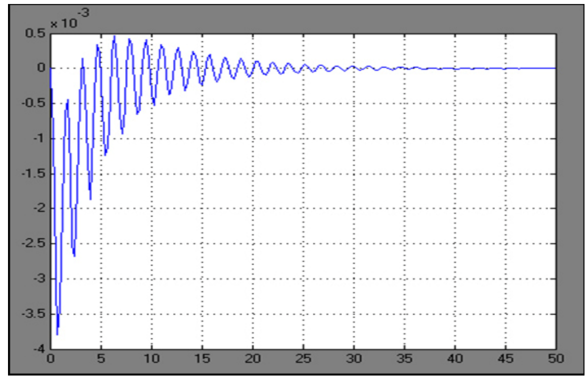

Fig. 6 Tie Line Steady at its nominal value using PI Controller

Fig 7 and Fig 8 shows the simulation results using PID Controller which shows the better dynamic performance than the PI Controller.

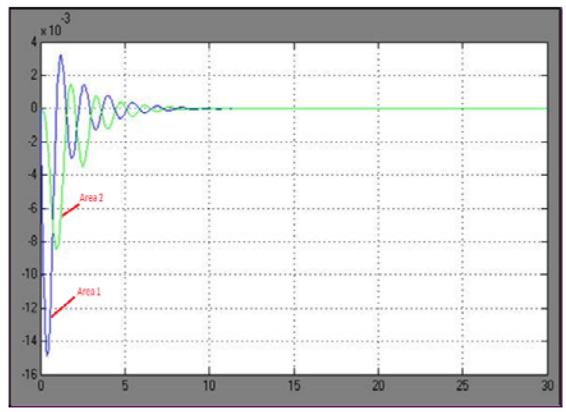

Fig. 7 Frequency steady at its nominal value due to secondary control loop using PID Controller

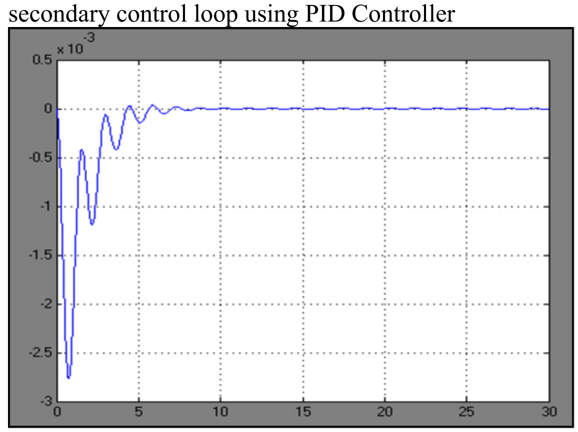

Fig. 8 Tie Line Steady at its nominal value using PID Controller

Figure 9 shows the comparison between PI and PID Controller.

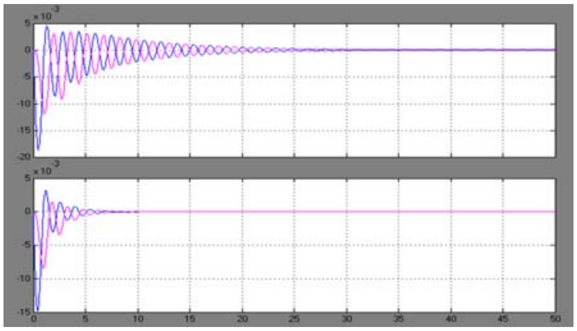

Fig 9 comparison between PI and PID controller

III. Fuzzy LOGIC CONTROLLER

Fuzzy logic is a problem-solving technique which provides a practicable way to understand and manually influence the mapping behaviour. Commonly, fuzzy logic provides simple rules to describe the system, rather than analytical equations.

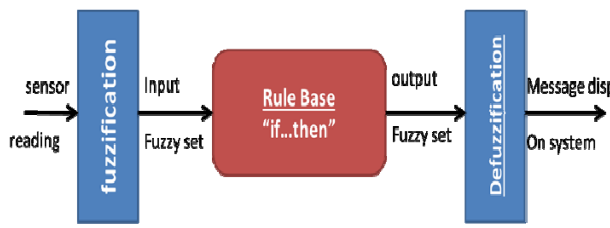

Fig.10 Fuzzy Logic Controllers

An FIS contains three main stages, the fuzzification stage, the rule base and the defuzzification stage. The fuzzification stage is used to transform the so-called crisp values of the input variables into fuzzy membership values. Then, these membership values are processed within the rule-base, using conditional 'if-then' statements. The outputs of the rules are summed and defuzzified into a crisp analogue output value.

Fuzzy logic modelling techniques could be classified into two categories, namely linguistic and Takagi-Sugeno-Kang (TSK). In linguistic models, such as Mamdani type. Here I have used Mamdani Type.

IV. Fuzzy Logic Membership function and Rules

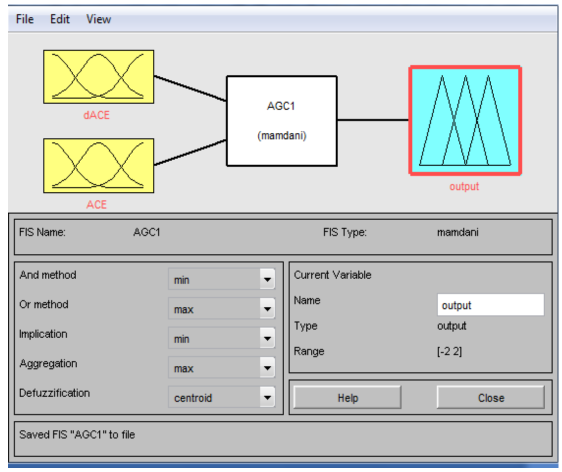

Fig. 11: Mamdani Type Fuzzy system for AGC system

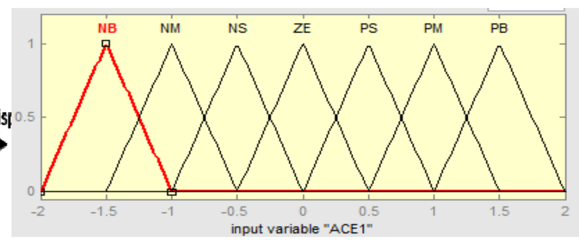

Fig.12a: input ACE1 membership function

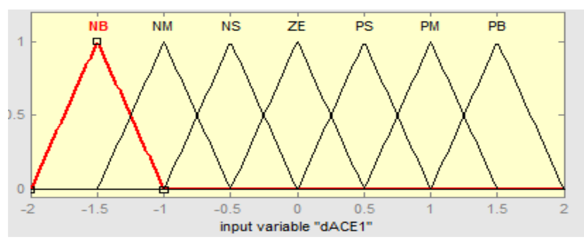

Fig. 12b: input dACE1 membership function

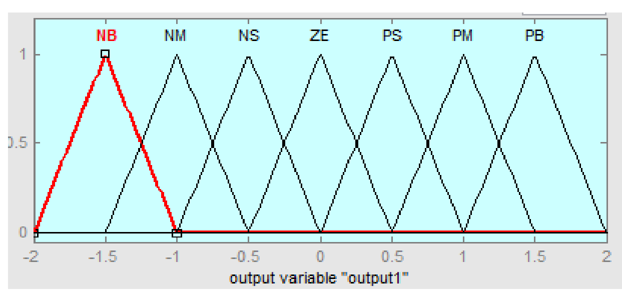

Fig. 12 c: output membership function

Rule Table of FLC

	NB	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	NB	NB	NM	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PM
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PM	PM	PB	PB	PB	PB

Table 1 Rule of Fuzzy Logic Controller:

NB – Negative Big **ZE** - Zero
PB – Positive Big **NM** – Negative Medium
PM – Positive Medium **NS** – Negative Small
PS – Positive Small

The AND and OR operators of Boolean logic exist in fuzzy logic, usually defined as the minimum and maximum, when they are defined this way, they are called the Zadeh operators. For Defuzzification Centroid method is used.

Rule Viewer

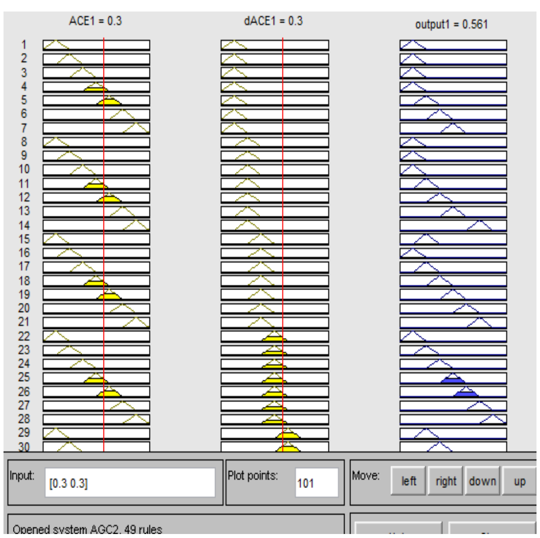

Fig.13: Rule Viewer

Surface Viewer

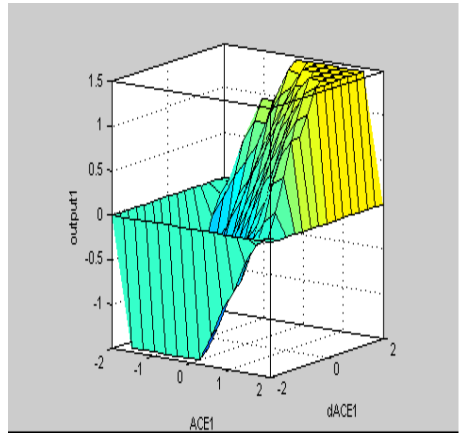

Fig. 14: Surface Viewer

V. SIMULINK MODEL FOR TWO-AREA SYSTEM USING FUZZY CONTROLLER

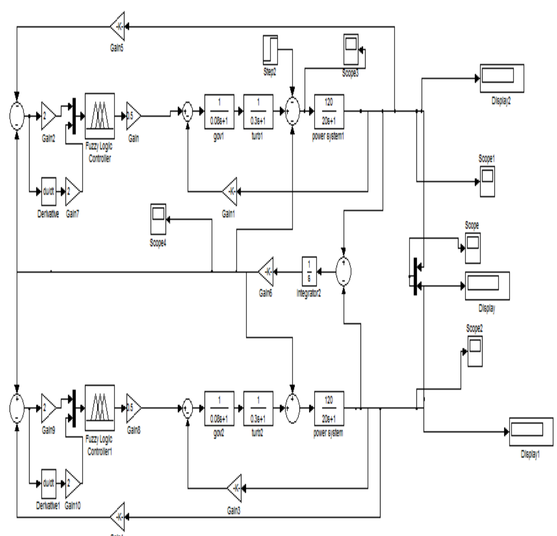

Fig. 15: Simulink model for Two-area System Using Fuzzy Controller

In this section, designing a fuzzy system to fine tuning and get more accurate result is considered. The Area Control Error and derivative of the Area Control Error are inputs and gets the output to fine tuning of Fuzzy controller.

The (small, medium, big) variables are used to define rules and membership function for the System Inputs and output and the ranges are (-2 to 2).

Simulation for Fuzzy Logic Controller

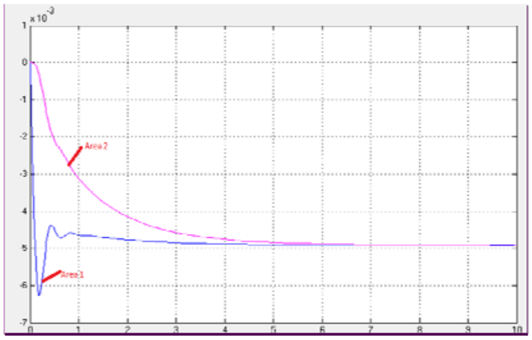

Fig. 16: Frequency steady at its nominal value due to secondary control loop by using Fuzzy logic controller

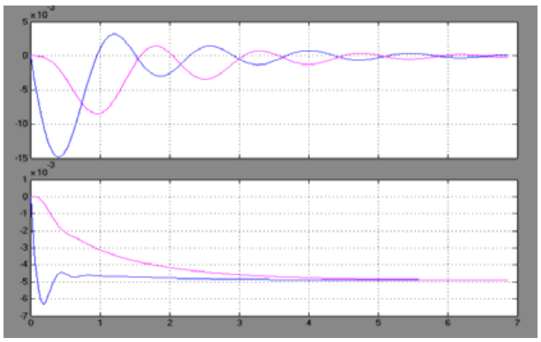

Fig. 17 Comparison between PID and Fuzzy Logic Controller

VI. SIMULATION RESULTS

By using **PI Controller** we get, Frequency and tie line deviation

f1 = 9.628 x 10-6

f2 = -8.49 x 10-6

Tie line = -1.311 x 10-7

And the frequency settling time is approx. 44 sec and the overshoot is 18 x 10-3.

By using **PID Controller** we get, Frequency and tie line deviation

f1 = 2.308 x 10-9

f2 = -1.349 x 10-11

Tie line = -6.511 x 10-11

And the frequency settling time is approx. 11 sec and the overshoot is 15 x 10-3.

Using **Fuzzy Controller**, it gives more accurate result than PID and PI controller. The Frequency Steady at its nominal value and the settling time & overshoot are 9 sec and 6 x 1 which is better with respect to conventional controller's results.

IX. Conclusion

Performance of PI controller and PID controller for Two-area , the result shows that PID gives better dynamic performance over PI Controller as the frequency settling time and overshoot decreases using PID controller respect to PI controller.

Performance of Fuzzy Logic Controller for Two-area , the result shows that it gives better dynamic performance over the conventional like PI & PID Controller as the settling time & overshoot decreases using Fuzzy Logic Controller.

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