# Load-Frequency Control of Multi Area Power Systems via constrained feedback control schemes

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*Abstract:* **In an interconnected power system, if a load demand changes arbitrarily, both frequency and tie line power differs. The principle point of load frequency control is to minimize the transient varieties in these variables furthermore to ensure that their steady state error is zero. Numerous cutting edge control procedures are utilized to execute a solid controller. The goal of these control strategies is to create and convey control dependably by keeping up both voltage and frequency within reasonable extent. At the point when real power changes system frequency gets affected while reactive power is subject to variety in voltage esteem. That is the reason real and reactive powers are controlled independently. Control of load frequency controls the active power. The role of automatic generation control (AGC) in power system operations with reference to tie line power under normal operating conditions is analyzed. This thesis studies the reliability of various control techniques of load frequency control of the proposed system through simulation in the MATLAB-Simulink environment.**

*Keywords:* **fuzzy logic controller, load frequency control, optimal controller, problem index.**

**Introduction**: Power systems are used to convert natural energy into electric power. They transport 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. It is well known that three-phase alternating current (AC) is generally used to transport the electricity. During the transportation, 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. When either of the two balances is broken and reset at a new level, the equilibrium points will float. A good quality of the electric power system requires both the frequency and voltage to remain at standard values during operation. For North America, the standard values for the frequency and voltage are *60 Hertz* and *120 Volts* respectively. However, the users of the electric power change the loads randomly and momentarily. It will be impossible to maintain the balances of both the active and reactive powers without control. As a result of the imbalance, the frequency and voltage levels will be varying with the change of the loads. 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. Although the active power and reactive power have combined effects on the frequency and voltage, the control problem of the frequency and voltage can be decoupled. The frequency is highly dependent on the active power while the voltage is highly dependent on the reactive power. Thus the control issue in power systems can be decoupled into two independent problems. One is about the active power and frequency control while the other is about the reactive power and voltage control. The active power and frequency control is referred to as load frequency control (LFC) [1].The foremost task of LFC is to keep the frequency constant against the randomly varying active power loads, which are also referred to as unknown external disturbance. Another task of the LFC is to regulate the tie-line power exchange error. A typical large-scale power system is composed of several areas of generating units. In order to enhance the fault tolerance of the entire power system, these generating units are connected via tie-lines. The usage of tie-line power imports a new error into the control problem, i.e., tie-line power exchange error. When a sudden active power load change occurs to an area, the area will obtain energy via tie-lines from other areas. But eventually, the area that is subject to the load change should balance it without external support. Otherwise there would be economic conflicts between the areas. Hence each area requires a separate load frequency controller to regulate the tie-line power exchange error so that all the areas in an interconnected power system can set their set points differently. Another problem is that the interconnection of the power systems results in huge increases in both the order of the system and the number of the tuning controller parameters. As a result, when modeling such complex high-order power systems, the model and parameter approximations can't be avoided [2]. Therefore, the requirement of the LFC is to be robust against the uncertainties of the system model and the variations of system parameters in reality. In summary, the LFC has two major assignments, which are to maintain the standard value of frequency and to keep the tie-line power exchange under schedule in the presences of any load changes [1].

## AUTOMATIC GENERATION CONTROL:

If the load on the system is increased suddenly then the turbine speed drops before the governor can adjust the input of the steam to the new load. As the change in the value of speed diminishes the error signal becomes smaller and the position of the governor & not of the fly balls gets closer to the point required to maintain the constant speed. One way to restore the speed or frequency to its nominal value is to add an integrator on the way. The integrator will unit shall monitor the average error over a period of time and will overcome the offset. Thus as the load of the system changes continuously the generation is adjusted automatically to restore the frequency to the nominal value. This scheme is known as automatic generation control. In an interconnected system consisting of several pools, the role of the AGC is to divide the load among the system, stations and generators so as to achieve maximum economy and reasonably uniform frequency.

**AGC IN A SINGLE AREA:**

With the primary LFC loop a change in the system load will result in a steady state frequency deviation, depending on the governor speed regulation. In order to reduce the frequency deviation to zero we must provide a reset action by introducing an integral controller to act on the load reference setting to change the speed set point. The integral controller increases the system type by 1 which forces the final frequency deviation to zero. The integral controller gain must be adjusted for a satisfactory transient response.

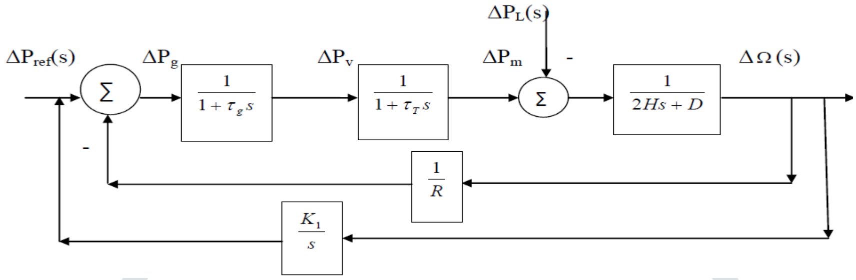


Figure 1: Mathematical modeling of AGC for an isolated power system.

The closed loop transfer function of the control system is given by:

$$\frac{\Delta\Omega(s)}{-\Delta P_L(s)} = \frac{s(1+t_g s)(1+t_t s)}{s(2Hs+D)(1+t_g s)(1+t_t s)+K_1+{}^{s}/_{R}}$$

**METHODS OF FEEDBACK CONTROL IMPLEMENTATION:**

**WITHOUT THE USE OF AGC**:

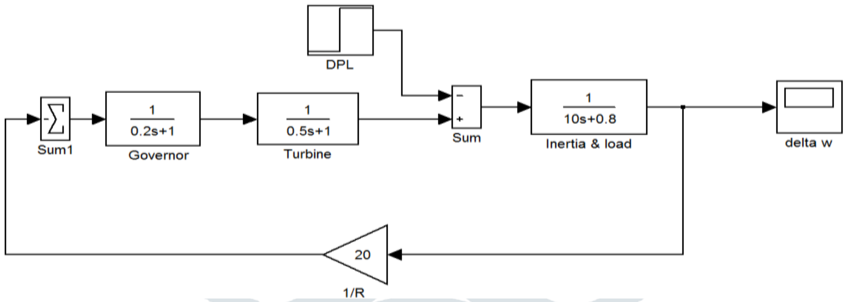


Fig 2: Simulation Block Diagram of the system without using AGC

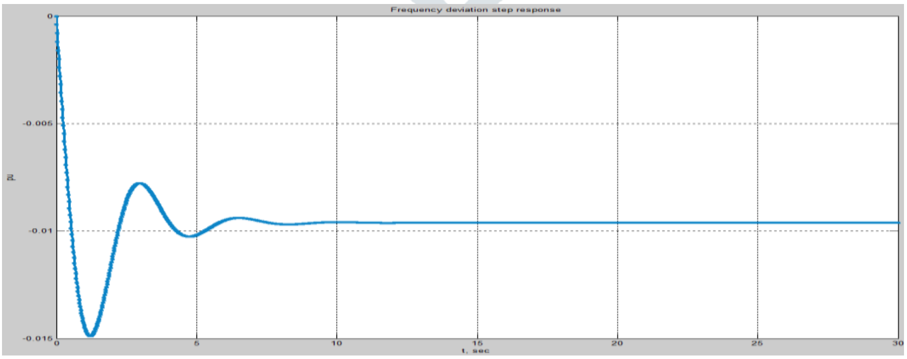


Fig 3: Frequency deviation step response without using AGC

The time domain specifications are:

Peak time= 1.223 Percentage overshoot= 54.80

Rise time= 0.418 Settling time= 6.8

**Single area with integral controller:**

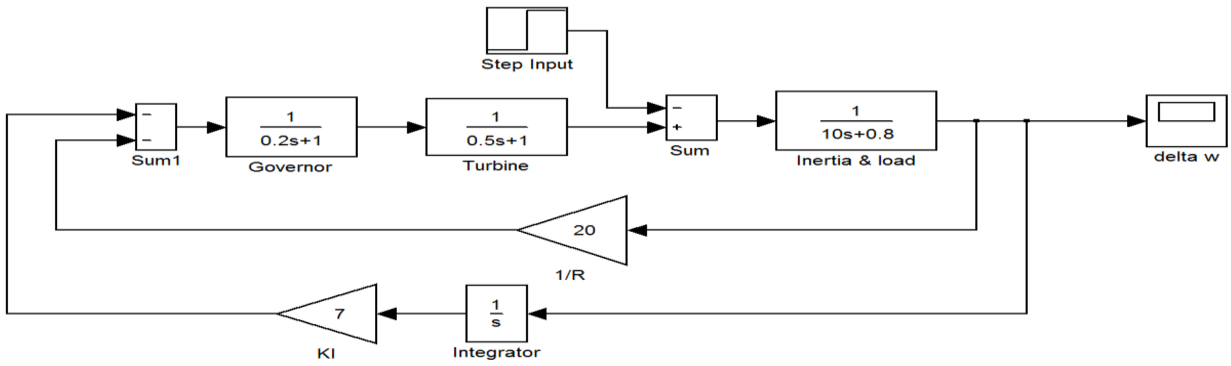


Fig 4: Simulation block diagram for the given system using AGC for an isolated system

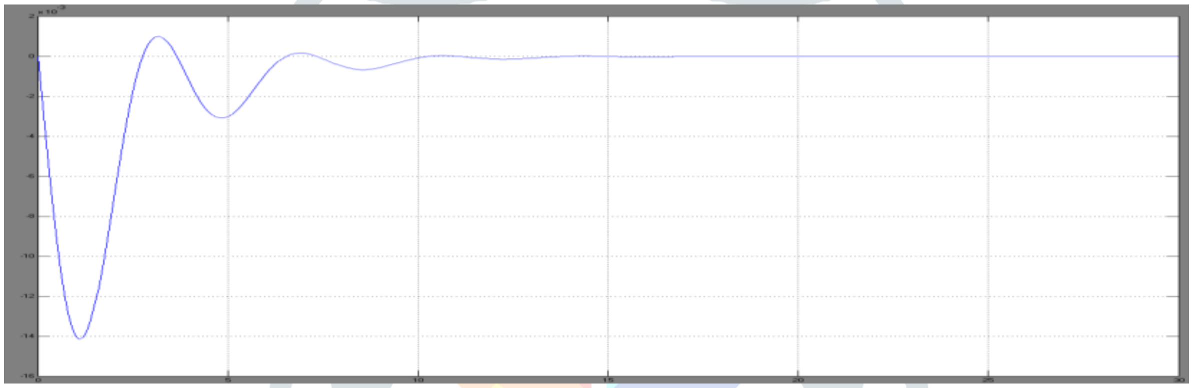

Fig 5: Frequency deviation step response using AGC

**OPTIMAL CONTROL SYSTEM:**

This is a technique that is applied in the control system design which is implemented by minimizing the performance index of the system variables. Here we have discussed the design of the optimal controllers for the linear systems with quadratic performance index, which is also known as the linear quadratic regulator. The aim of the optimal regulator design is to obtain a control law **u*(x, t)** which can move the system from its initial state to the final state by minimizing the performance index. The performance index which is widely used is the quadratic performance index.

**LOAD FREQUENCY CONTROL USING OPTIMAL CONTROL DESIGN:**

Performance index is given as:

$$J = 0\int_0^{\infty} (20x_1^2 + 15x_2^2 + 5x_3^2 + 0.15u^2)$$

MATLAB CODE:

```
PL=0.2;

A = [-5 0 -100; 2 -2 0; 0 0.1 -0.08];

B = [0; 0; -0.1]; BPL=PL*B;

C = [0 0 1];

D = 0;
```

```
Q = [20 0 0; 0 10 0; 0 0 5];

R = .15;

[K, P] = lqr2(A, B, Q, R)

Af = A - B*K

t=0:0.02:1;

[y, x] = step(Af, BPL, C, D, 1, t);

plot(t, y), grid

xlabel('t, sec'), ylabel('pu')
```

In general there are two situations where the compensation is required. The first case is when the system is unstable. The second case is when the system is stable but the settling time is more. Hence using pole placement technique is nothing but using the compensation scheme to reduce the settling time of the system. It is clearly shown that the system reached faster to a steady state in compensated system than for an uncompensated system.

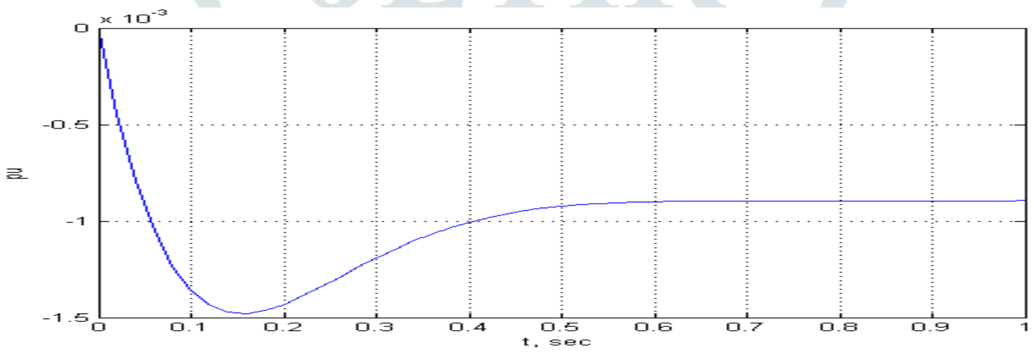

Fig 6: Frequency deviation step response of LFC using optimal control design

**Three Area Load frequency control using Fuzzy logic controller:**

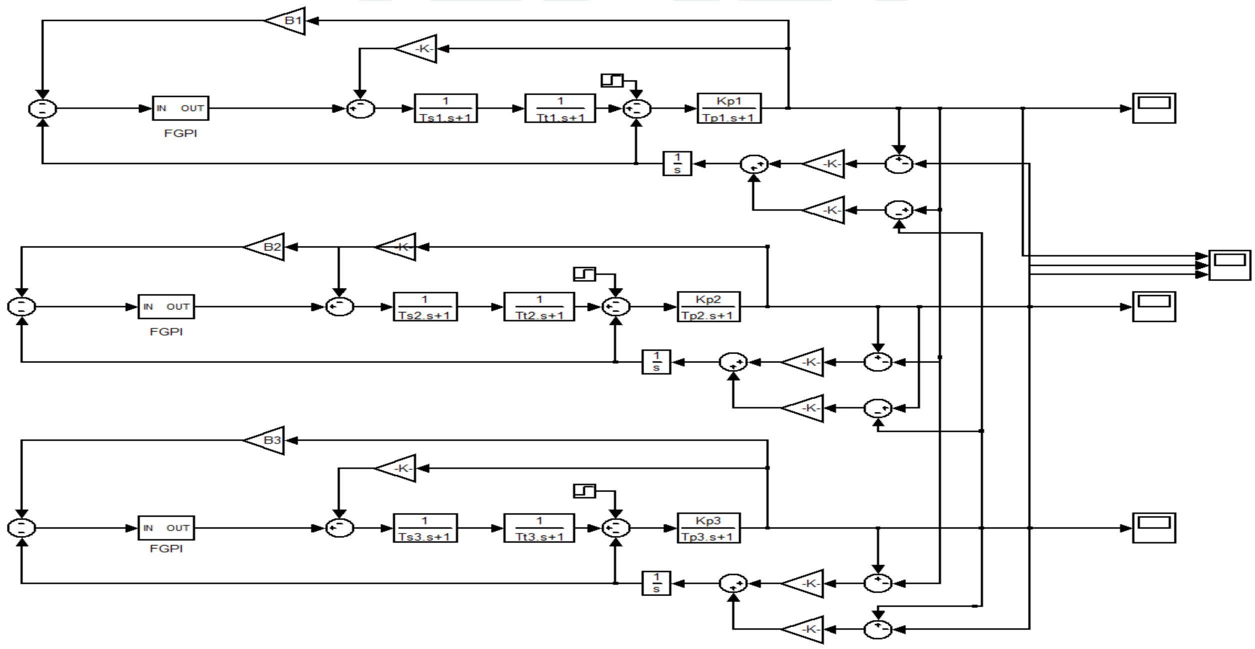

Fig 7: Simulation block diagram for the given system using AGC for an isolated system

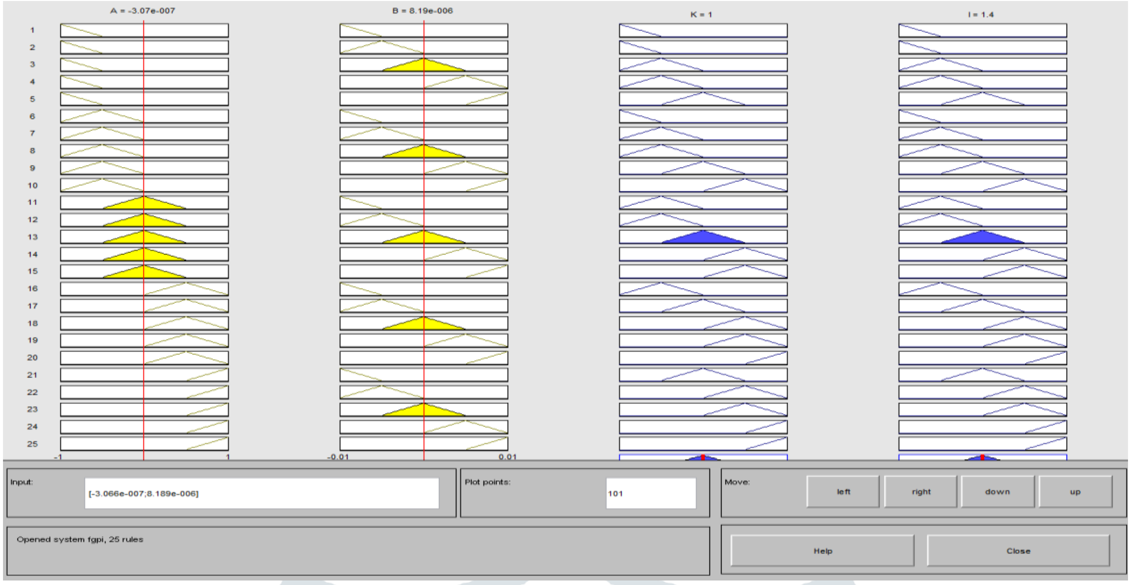


Fig 8: Fuzzy rule viewer for three area system


Fig 9: Membership functions of fuzzy system

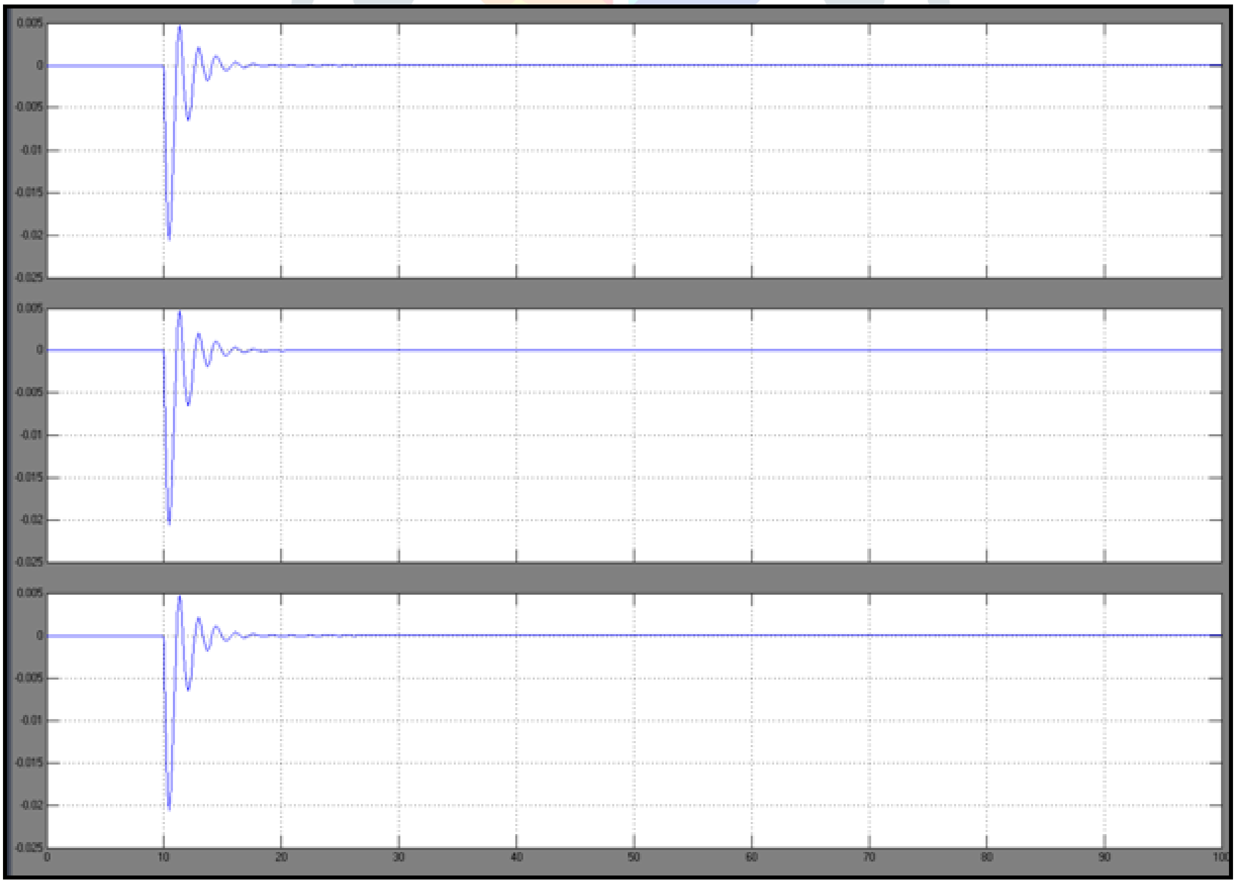

Fig 10: Frequency deviation response of LFC using fuzzy logic controller

**Conclusion**

This paper shows designing a controller that can withstand optimal results in a single area and three area power systems when the input parameters of the system are changed. Three methods of Load Frequency Control were studied taking an isolated power system into account. It was seen that the Automatic Generation Control was better than the conventional uncompensated system in terms of steady state frequency deviation. The Pole Placement Control was seen to have better results than the AGC in terms of settling time. Finally the Optimal controller design provided the best results in terms of both frequency deviation and settling time and achieved required reliability when the input parameters were changed.

For multi area system we design the fuzzy logic controller to mitigate the frequency error when sudden increment of load in the system, the step function is used as a sudden change in load and it cause frequency deviations in three areas frequency response. Secondly there's introduction of fuzzy logic controller to change the values of the various parameters present in the power system under investigation so it can cope up with the changes in the load demand. As a result of which the changes the frequency and also the tie line power is reduced and also the stability of the system is maintained. It is also seen that fuzzy logic technique has quicker convergence characteristics. The investigation has been done for single area system and multi area systems and the result is being given accordingly.

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