

Load Frequency Control in Three Areas System by using Fuzzy Logic Controller And Fuel Cell

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Abstract - Load frequency controllers are required to operate effectively under increasingly restrictive conditions. These include highly varying random fluctuations in power demand which changes the operating point of the power system, in turn resulting in parametric changes and uncertainties in the power system. The frequency and tie line power deviations need to be regulated in minimum time within narrow limits. The paper present analysis on dynamic performance of Load Frequency Control (LFC) of three area interconnected thermal – thermal –hydropower system by the use of Fuzzy Intelligence. In the proposed scheme, control methodology is Fuzzy Logic Control for three area interconnected thermal power system. In this proposed scheme three fuzzy logic controllers for each area is implemented to get zero frequency deviations. The dynamic model of the power system and the controller design are elaborated in the paper. The controller performances are simulated using MATLAB/SIMULINK simulation software. Fuzzy Logic Controller is Rule based which depends upon various inputs. It provides better performance and efficiency. Simulation is done using three Controllers for different inputs in MA TLAB/SIMULINK software.

Key Words: Load frequency control, Fuzzy Logic Control, Automatic generation control, PID Controller.

1.INTRODUCTION

This The dynamic behaviour of many industrial plants is heavily influenced by disturbances and, in particular, by changes in the operating point. This is typically the case for power systems Ref [1]. Load-frequency control (LFC) in power systems is very important in order to supply reliable electric power with good quality. The goal of LFC is to maintain zero steady state errors in a multi-area interconnected power system Ref [2]. In addition, the power system should fulfil the requested dispatch conditions. In practice, power systems generally have more than two areas and each area is different than others. Because of this, in the study, the power system with three areas that consist of three thermal units Ref [3]. 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.

Load Frequency Control is one of the major requirements in providing reliable and quality operation in multi-area power systems. Load Frequency control has received great attention of researchers in recent years also many control strategies have been developed Ref [1]. To regulate a signal known as area control error (ACE) load interchange power with neighbouring areas connected through tie lines. A control strategy is needed that not only maintains constancy of frequency and desired tie power flow Ref [4] but also be able to achieve zero steady state error and inadvertent interchange. AGC is the essential service in maintaining the system integrity by matching generation and demand in real-time. The aim of this paper is to stabilize the system frequency for step load disturbances with the help of Fuzzy Logic Controller[5].

2. POWER SYSTEM MODELLING AND PROBLEM FORMULATION

A three area interconnected power system is shown in fig.1 where three control areas are connected by tie-lines. In each control area, all generators are assumed to form a coherent group Ref[6]. The three areas are considered thermal thermal- hydro with same parameters. The change in valve positions due to LFC of three areas are given by

$$\Delta X_{E1}(s) = [\Delta P_{C1}(S) - \frac{1}{R1}\Delta F_1(S)] \left[\frac{1}{1+S\tau_{sg1}} \right] \quad (1)$$

$$\Delta X_{E2}(s) = [\Delta P_{C2}(S) - \frac{1}{R2}\Delta F_2(S)] \left[\frac{1}{1+S\tau_{sg2}} \right] \quad (2)$$

$$\Delta X_{E3}(s) = [\Delta P_{C3}(S) - \frac{1}{R3}\Delta F_3(S)] \left[\frac{1}{1+S\tau_{sg3}} \right] \quad (3)$$

The changes in turbine power are given by

$$\Delta P_{G1}(S) = \left[\frac{1}{1+S\tau_{sg1}} \Delta X_{E1}(s) \right] \quad (4)$$

$$\Delta P_{G2}(S) = \left[\frac{1}{1+S\tau_{sg2}} \Delta X_{E2}(s) \right] \quad (5)$$

$$\Delta P_{G3}(S) = \left[\frac{1}{1+S\tau_{sg3}} \Delta X_{E3}(S) \right] \quad (6)$$

The frequency deviations of each control areas are

$$\Delta F_1(S) = \left[\frac{K_{ps1}}{1+S\tau_{sg1}} \right] [\Delta P_{G1}(S) - \Delta P_{D1}(S) - \Delta P_{TL1}(S)] \quad (7)$$

$$\Delta F_2(S) = \left[\frac{K_{ps2}}{1+S\tau_{sg2}} \right] [\Delta P_{G2}(S) - \Delta P_{D2}(S) - \Delta P_{TL2}(S)] \quad (8)$$

$$\Delta F_3(S) = \left[\frac{K_{ps3}}{1+S\tau_{sg3}} \right] [\Delta P_{G3}(S) - \Delta P_{D3}(S) - \Delta P_{TL3}(S)] \quad (9)$$

The tie line power deviations for three control areas are

$$\Delta P_{TL1}(S) = \frac{2 \pi T_{12}}{S} [\Delta F_1(S) - \Delta F_2(S)] + \frac{2 \pi T_{13}}{S} [\Delta F_1(S) - \Delta F_3(S)] \quad (10)$$

$$\Delta P_{TL2}(S) = \frac{2 \pi T_{21}}{S} [\Delta F_2(S) - \Delta F_1(S)] + \frac{2 \pi T_{23}}{S} [\Delta F_2(S) - \Delta F_3(S)] \quad (11)$$

$$\Delta P_{TL3}(S) = \frac{2 \pi T_{31}}{S} [\Delta F_3(S) - \Delta F_1(S)] + \frac{2 \pi T_{32}}{S} [\Delta F_3(S) - \Delta F_2(S)] \quad (12)$$

Turbine reference power of each area is tried to be set to its nominal value by an integral controller and the input of the integral controller of each area is known as area control error(ACE) of the same area. The same for three areas are.

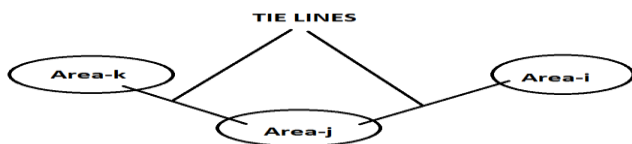


Fig.1 Equivalent of three areas Power System

$$ACE1(S) = \Delta P_{TL1}(S) + b_1 \Delta F_1(S) \quad (13)$$

$$ACE2(S) = \Delta P_{TL2}(S) + b_1 \Delta F_2(S) \quad (14)$$

$$ACE3(S) = \Delta P_{TL3}(S) + b_1 \Delta F_3(S) \quad (15)$$

ACE1 = Area control error of area 1,

ACE2 = Area control error of area 2,

ACE3 = Area control error of area 3.

Nomenclature

F(s) :Nominal system frequency,xE : Valve movement, Pc : Command power, R : Speed governor droop

D: Machine damping Keg Speed governor gain, sg: Speed governor time constant, Kt: Turbine gain, Γt: Turbine time constant, Kps: Machine gain, Γps:Machine time constant, PG: Turbine output power,

Kt: Turbine gain,Γt: Turbine time constant, PD: Power demand, PTL: Tie line power (steady state), Tij : Synchronizing coefficient (i= 1,2,3; j=1,2,3; where i ≠ j), b : Frequency bias

3. POWER FREQUENCY CONTROL METHODOLOGY

PI Controller -One of the most widely used controls with thermal and hydro power plants governing systems is the PI type controller. The proportional-integral controller generates an output signal consisting of two terms- one proportional to error signal and the other proportional to the integral error signal. Due to the faster transient response Proportional controller is used to achieve the steady state condition much quicker. The proportional term of the controller produces a control signal proportional to the error in the system, so that $u(t) = K_p * e(t)$. Typically, given a step change of load demand, low values of K_p give rise to stable responses with large steady-state errors. Higher values of K_p give better steady-state performance, but worst transient response. Therefore, the higher value of K_p is used to reduce the steady state error, although increasing the gain K_p decreases the system time constant and damping. Therefore it is evident to choose the optimum value of K_p . The proportional action can never eliminate the steady state error.

Fuzzy Logic Controller - Fig. 2 shows the fuzzy inference system Ref[7], to implement fuzzy logic technique to a real application requires the following three steps:

- 1) Fuzzification: convert classical data or crisp data into fuzzy data or Membership Functions (MFs) as shown in fig. 3.
- 2) Fuzzy Inference Process: combine membership functions with the control rules to derive the fuzzy output.
- 3) Defuzzification: use different methods to calculate each associated output and put them into a table: the lookup table. It picks up the output from the lookup table based on the current input during an application.

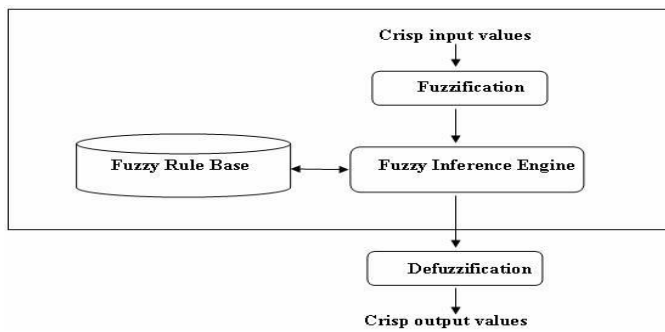


Fig. 2 Diagram of fuzzy inference system

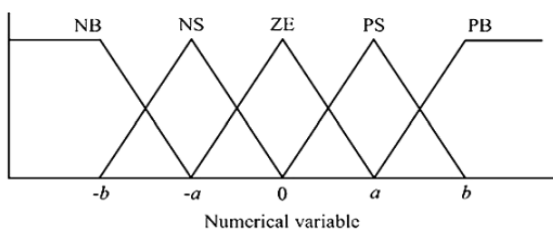


Fig. 3 Fuzzy logic controller inputs and output membership function.

The application of fuzzy controller for load-frequency control in power systems is used. For the same interconnected power system having three control areas including same turbine units, same properties and physical constants of the areas above are considered in the simulation. In the simulation, a step load increment in the three areas of power system is considered.

4. SIMULATIONS AND RESULT

The area control error for each area is controlled with FLC to optimize the integral coefficient and hence to achieve the zero frequency steady state error. The fuzzy logic controller model in Matlab/Simulink is shown in the fig 4.

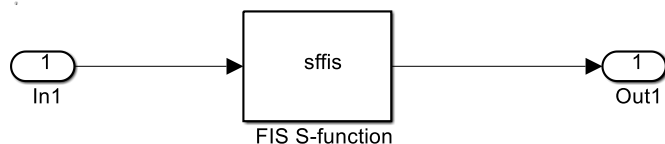


Fig. 4 Fuzzy logic controller using S function

RESULT

The simulations are done on Matlab/Simulink environment for the three area control. A step disturbance is considered for the three same areas. With the help of fuzzy controller, the frequency deviations are set to zero with minimum settling time and overshoot.

Frequency response of interconnected power system is show in fig5. The x-axis is representing the time and y-axis is representing the frequency deviation. In the initial time the frequency is dropped due to internal as well as external reasons. The frequency is maintained by fuzzy logic controller and PID controller as show in fig 5. Blue line indicate the frequency is maintained by PID controller and black line indicate the frequency is maintained by fuzzy logic controller.

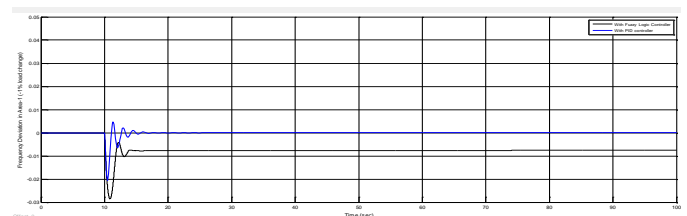


Fig 5. Frquence response by using Fuzzy logic controller and PID controller

Frequency deviation for area one:

Frequency response of Area one power system is show in fig 6. The x-axis is representing the time and y- axis is representing the frequency deviation. In the initial time the frequency is dropped due to internal as well as external reasons. Frequency is maintained by fuzzy logic controller r as show in the below fig.

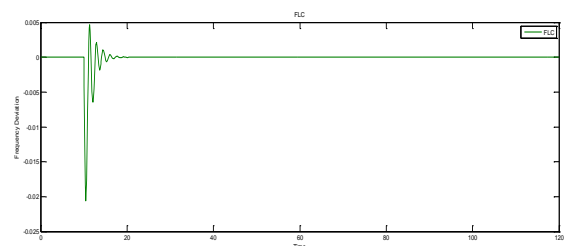


Fig.6. Plot for change in frequency for Area one

Frequency deviation for area Two:

Frequency response of Area two power system is show in fig 7. The x-axis is representing the time and y- axis is representing the frequency deviation. In the initial time the frequency is dropped due to internal as well as

external reasons. Frequency is maintained by fuzzy logic controller as show in the below fig.

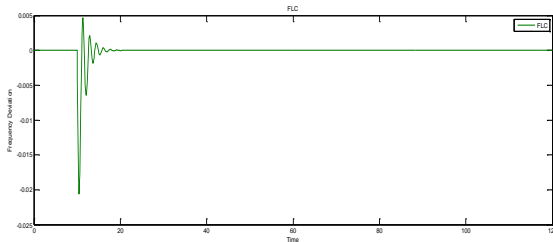


Fig.7. Plot for change in frequency for Area Two

Frequency deviation for area Three:

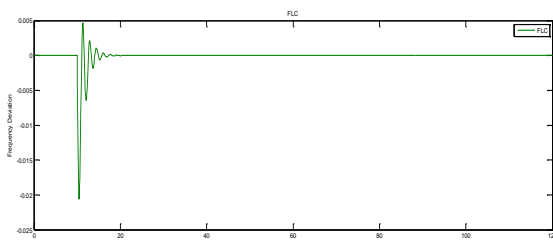


Fig.8. Plot for change in frequency for Area Three

Frequency response of Area three power systems is show in fig8. The x-axis is representing the time and y- axis is representing the frequency deviation. In the initial time the frequency is dropped due to internal as well as external reasons. Frequency is maintained by fuzzy logic controller as show in the above fig.

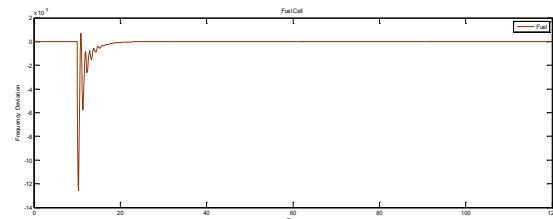


Fig.9: Frequency deviation of fuel cell

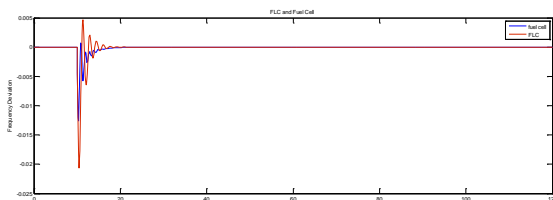


Fig.10: Frequency deviation of FLC and fuel cell

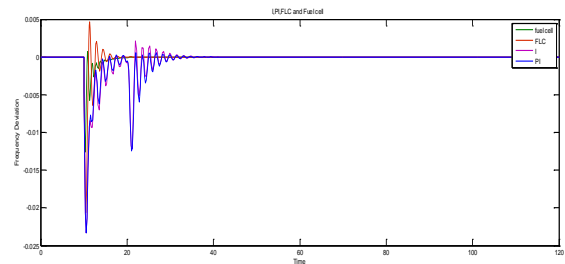


Fig.11: Frequency deviation of I,PI, FLC and fuel cell

5. CONCLUSION

With this technique the frequency of the whole system i.e. area I , area II and area III is better regulated and the frequency regulator response In this study, FLC application to three area generation controls is considered for the frequency deviations of each area. The transient behaviour of frequency for the load perturbation in areas is studied. The study, the power systems with three areas that consist of thermal hydro thermal units are considered. The simulation results obtained shows the performance of FLC controller against to the load perturbation at each area in the considered power system.

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