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Design of Fuzzy Logic Controller based Load Frequency Control for Multi Source Multi Area System

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***Abstract:-* The power system became highly complex due to rapid growth of industries. The active power demand of industries keeps varying, which leads to change in system frequency. It is corrected with the help of Load Frequency Controller (LFC).The load on the power system is always varying with respect to time which results in the variation of frequency, thus leading to load frequency control problem (LFC). The variation in the frequency is highly undesirable and maximum acceptable variation in the frequency is ± 0.5 Hz. In this paper load frequency control is done by PI controller, which is a conventional controller. This type of controller is slow and does not allow the controller designer to take into account possible changes in operating conditions and non-linearity's in the generator unit. In order to overcome these drawbacks a new intelligent controller such as fuzzy controller is presented to quench the deviations in the frequency and the tie line power due to different load disturbances. The effectiveness of the proposed controller is confirmed using MATLAB/SIMULINK software. The results shows that fuzzy controller provides fast response, very less undershoot.**

***Keywords* – PI controller, Fuzzy controller, multi area power system, load frequency control, MATLAB SIMULINK**

I-INTRODUCTION

In order to keep the system in the steady-state, both the active and the reactive powers are to be controlled. The objective of the control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while maintaining the voltage and frequency with in permissible limits.

Changes in real power mainly affect the system frequency, while the reactive power is less sensitive to the changes in frequency and is mainly dependant on the changes in voltage magnitude. Thus real and reactive powers are controlled separately.

The load frequency control loop (LFC) controls the real power and frequency and the automatic voltage regulator regulates the reactive power and voltage magnitude [3] Load frequency control has gained importance with the growth of interconnected systems and has made the operation of the interconnected systems possible. In an interconnected power system, the controllers are for a particular operating condition and take care of small changes in load demand to maintain the frequency and voltage magnitude within the specified limits [4]

II. REASONS FOR KEEPING CONSTANT FREQUENCY

Following are the reasons for keeping a strict limit on the system frequency variation: The speed of the alternating current motors depends on the frequency of the power supply. There are situations where speed consistency is expected to be of high order. The electric clocks are driven by the synchronous motors. The accuracy of the clocks are not only dependent on the frequency but also is an integral of the frequency error. If the normal frequency 50 Hertz and the system frequency falls below 47.5 Hertz or goes up above 52.5 Hertz then the blades of the turbine are likely to get damaged so as to prevent the stalling of the generator. The under frequency operation of the power transformer is not desirable. For constant system voltage if the frequency is below the desired level then the normal flux in the core increases. This sustained under frequency operation of the power transformer results in low efficiency and over-heating of the transformer windings. The most serious effect of subnormal frequency operation is observed in the case of Thermal Power Plants. Due to the subnormal frequency operation the blast of the ID and FD fans in the power stations get reduced and thereby reduce the generation power in the thermal plants. This phenomenon has got a cumulative effect and in turn is able to make complete shutdown of the power plant if proper steps of load shedding technique is not engaged. It is pertinent to mention that, in load shedding technique a sizable chunk of load from the power system is disconnected from the generating units so as to restore the frequency to the desired level.

III. MATHEMATICAL MODELING

The thermal power plant in both the areas consists of speed governor acting as a primary controller. It helps to match generation with the demand by controlling the steam input to the turbine. The reference power setting of the governor is varied by the secondary controller for fine tuning of the frequency. The speed governor equation is

$\Delta Pg = \Delta Pref - \frac{1}{R}\Delta f$………………. (1)

Hydraulic amplifier acts against high pressure steam into the turbine based on governor. The mathematical representation of hydraulic amplifier is:

$\Delta PH = \frac{1}{1+STH} \Delta Pg$ ……………… (2)

The governor controls the steam input to the non-reheat turbine acting as a prime mover for the generator which in turn supplies energy to the power system. Non-reheat turbine is expressed as:

$\Delta PT = \frac{1}{1+STT} \Delta PH$……………………… (3)

The operation of the hydro power plant is similar to thermal power plant. The speed governing mechanism of hydro power plant with hydraulic amplifier is represented as:

$\Delta PHV = \left(\frac{K1}{1+ST1}\right)\left(\frac{1+STR}{1+ST2}\right) \Delta Pref - \frac{1}{R}(\Delta f)$..(4)

Hydro turbines used in hydro power plants has different characteristics from thermal turbines and is represented by:

$\Delta PHT = \frac{1-STW}{1+0.5STW} \Delta PHV$………………….. (5)

The turbine output power becomes an input to the generator for feeding electrical power to the power system. The generator along with the power system with the load disturbance is expressed as:

$\Delta PT - \Delta PD = \frac{KP}{1+STP} \Delta f$…………………… (6)

The power is transferred between the areas via tie line and is represented by:

$\Delta Ptie12 = \frac{2\pi T}{s}(\Delta f1 - \Delta f2)$………….. (7)

IV. DIFFERENT TYPES OF CONTROLLER

4.1PI controller

A controller in the forward path, which changes the controller output corresponding to the proportional plus integral of the error signal is called PI controller. The PI controller increases the order of the system, increases the type of the system and reduces steady state error tremendously for same type of inputs.

4.2 Fuzzy controller

In control systems, the inputs to the systems are the error and the change in the error of the feedback loop, while the output is the control action. The general architecture of a fuzzy controller is depicted in Fig 4.1To implement fuzzy logic technique to a real application requires the following three steps:

Fuzzification- Convert Classical data or Crisp data into fuzzy data or membership functions (MF).

Fuzzy Interference Process- Combine membership functions with the control rules to derive the fuzzy output.

Defuzzification- use different methods to calculate each associated output and put them into a table: the lookup. Pick up the output from the look-up table based on the current input during an application.

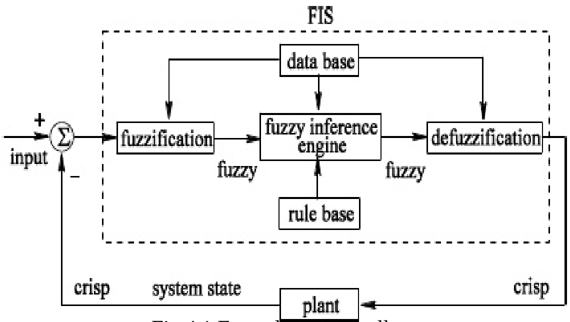


Fig 4.1 Fuzzy logic controller

V.PI CONTROLLER TUNUNG METHOD

In control systems, PI controller is used as a generic control feedback loop mechanism The proportional term reduces the transient behavior of the system and the integral term eliminates steady-state error, thereby improves the stability of the system. The PI controller is implemented as secondary controller in LFC, which sets the reference power setting of the governor present in each plant of the respective area. The PI secondary LFC controller
is expressed by:

$\Delta Pref = \left(KP + \frac{Ki}{s}\right) ACE$ ………………… (8)

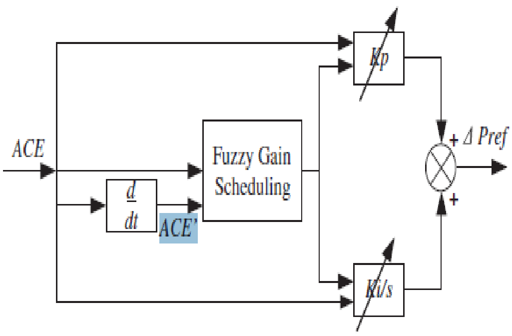
In this paper, the gain values of PI controller are tuned using ZN Method and fuzzy logic control method.

5.1 ZN method

The PI tuning proposed by Ziegler and Nichols is a standard method developed empirically through the simulation of a large number of process systems to provide a simple rule.

5.2 Fuzzy Logic method

In the PI controller, the gain values are fixed irrespective of the system changes. To obtain better response, the gain values are be varied based on the system variations. So, fuzzy is used for scheduling the gains of the PI controller. The Fuzzy Gain Scheduling (FGS) for multi source multi area hydrothermal power plant is shown in Fig



5.1

Figure 5.1 Block Diagram of fuzzy gain scheduling

The Fuzzy system used for scheduling the gain of proportional and integral controller has two inputs, ACE and ACE'. The output of FGS is Kp of proportional and Ki of integral controller.

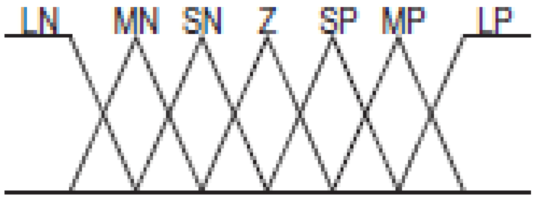


Fig 5.1.1Membership function

Seven membership functions namely Large Negative (LN), Medium Negative (MN), Small Negative (SN), Zero (Z), Small Positive (SP), Medium Positive (MP) and Large Positive (LP) are used as linguistic variables for the inputs and output. Out of these, LN and LP are made trapezoidal to accommodate any value beyond the range The rest are triangular shaped as shown in Fig. 5.1.1 The ranges for inputs DACE, DACE1 and output gain based on open loop response are [_-2 to 2], [-2 to 2] respectively. The rule base for the FGS is developed and furnished in Table 5.1The rules are framed such that, it can be used for scheduling both Kp and Ki.

ACE/ACE'	LN	MN	SN	Z	SP	MP	LP
LN	LP	LP	LP	MP	MP	SP	Z
MN	LP	MP	MP	MP	SP	Z	SN
SN	LP	MP	SP	Z	Z	SN	MN
Z	LP	MP	SP	SN	SN	MN	MN
SP	MP	SP	Z	SN	SN	MN	LN
MP	SP	Z	SN	MN	MN	MN	LN
LP	Z	SN	MN	LN	LN	LN	LN

Table 5.1 Fuzzy rule

VI. SIMULATION RESULTS OF MULTI-AREA LFC

6.1Simulation of LFC Control using PI controller:

The general LFC system and their characteristics curves are simulated using the MATLAB software which is shown in Figure 6.1. The simulation shows the LFC system using PI controller which is model in transfer function model using mathematical expression discussed in chapter 3

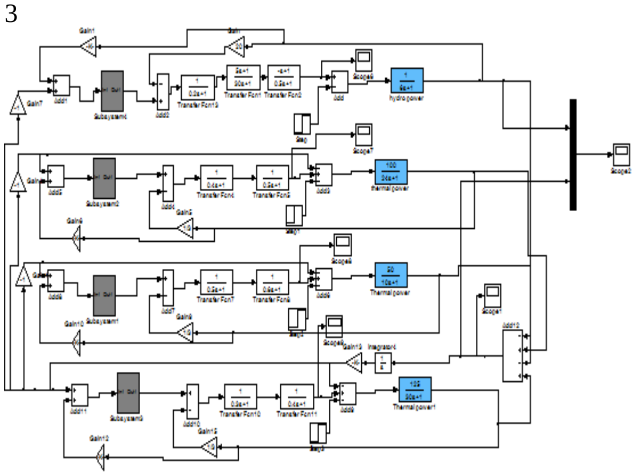


Figure 6.1 LFC SYSTEM USING PI CONTROLLER

The transfer function model consist of governor, turbine and generator model which is derived to form a model for single area system. Similarly, the hydro system is modelled from governor , penstock and valve, generator model and power system model. These modelling is derived and then equated with power system values to obtain a desired values for the gain and time constant. Each and every block consist of time and gain values ($K_p, K_g, K_T, K_R, T_g, T_p, \& T_T$).The gain values which have been used in the simulation have been obtained with referance towards the valuues in the form of state space model. The frequency deviation due to change in load condition can be obtained in the output waveform. The PI controller is connected with the power system model and also the feedback system which is capable to analyse the input as well as the output of the system from frquency deviation. The PI controller is an existing system control which analyse the system using the comparative to check the error signal caused by the output. It analyse the gain values and tuned the desired using different kinds of technics. Thus the desired gain values are obtained from the PI controller to regulate the sudden change in the load. The parameter values are shown in table 6.1.

Gain	Values	Time	Values
Kp	1	Tp	0.2
Kg	5	Tg	30
Kt	1	Tt	0.5
Kp_1	1	Tp_1	0.4
Kg_1	5	Tg_1	20
Kt_1	0.5	Tt_1	0.3
Kp_2	1	Tp_2	0.5
Kg_2	50	Tg_2	10
Kt_2	1	Tt_2	0.6
A_{12}	0.3433	$A2_3$	0.533

Table 6.1 Transfer function model PI controller parameter values

The output waveform for the above simulation has been shown in the Figure 6.2. The output waveform shows the frequency deviation occurs at a time interval of between 0-50 sec which is the time taken by the controller to obtain the steady state which is able to attain at steady error equal to zero. These curves shows the change in dynamic condition of the system which can be categorized based on the gain and the area control error values. The output characteristics shows the change in the error causes the change in the PI controller tuning for each and every part of the controller to obtain the steady state condition.

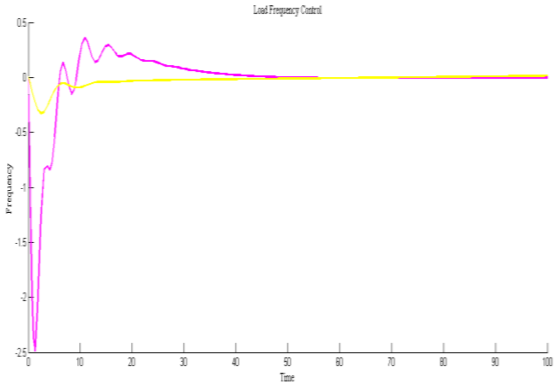


Figure 6.2 PI Controller Waveform

The main drawbacks of the PI controller is the time taken to reduce the load deviation is high and also the sensing of the error signal makes the system more complicate. The tuning of PI controller is quite not easy to obtain the steady state condition.

6.2 Simulation of LFC Control using FLC (fuzzy logic controller)

Variable structure fuzzy gain scheduling is proposed for solving the load frequency control problem of multi-source multi area hydro-thermal power system. The three control areas are connected via tie line. Each area comprises of both hydro and thermal power plant. The area frequency and tie line power oscillates during load variations are controlled by primary governor controller and secondary Proportional Integral (PI) controller. The PI controller gains are tuned using fuzzy logic control variable structure fuzzy gain scheduling provides better response for multi source multi area hydro thermal power system.

6.2.1 Transfer Function Model

The transfer function model of the proposed system is shown in Figure 6.3. The LFC model consists of a transfer function model of the governor, turbines and generator. The FUZZY logic transfer function model consists of, gain model and tie line model. The transfer function model is obtained from mathematical model of the LFC which is described in chapter 3.

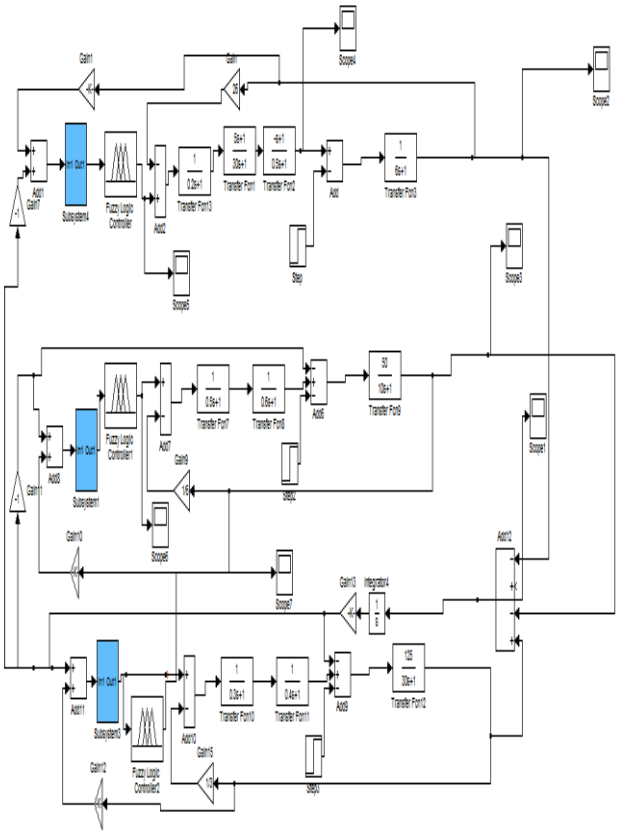


Figure 6.3 Transfer Function Model

The Figure 6.3 described the complete transfer function model for the LFC .in this transfer function model consists of three single area system, area1 thermal plant, area 2 thermal plant and area 3 hydro plant. This three single area is connected with help of tie line The speed governor of the synchronous generator play a vital role in the energy conversion process, It converts kinetic energy into mechanical energy with help of turbines. Thus the for obtaining a stability of the power system the governor model should be taken into consideration.The turbine model, which is connected as a input to the synchronous generator where mechanical energy is converted into the electrical energy.

It analyse the gain values and tuned the desired using different kinds of technics. Thus the desired gain values are obtained from the PI controller to regulate the sudden change in the load. The parameter values are shown in table 6.2. These can be obtained through the definite function for the different controller. This system can be able define an equal set of values.

Gain	Values	Time	Values
Kp	1	Tp	0.3
Kg	6	Tg	35
Kt	1.2	Tt	0.5
Kp_1	1	Tp_1	0.4
Kg_1	5	Tg_1	20
Kt_1	1	Tt_1	0.2
Kp_2	1	Tp_2	0.5
Kg_2	50	Tg_2	10
Kt_2	1	Tt_2	0.6
A_{12}	0.4433	A_{23}	0.633

Table 6.2 Transfer function model FLC parameter values

In this study it has been assumed that the load is not constant it is various from time to time if load change frequency deviation occurs this frequency deviation affect the overall system efficiency at a time we maintain the constant frequency (50Hz) with help of PI controller tuning process of FLC. The output waveform for the above simulation has been shown in the Figure 6.4. The proposed system provides the tuning of controller is performed using the Mamdani based controller which is able to determine from the membership function to form different set of values which is formed in the input and output. The rules are framed with the reference as well as the predefined values which can be able to function based on the fuzzy control. The fuzzy output is able to obtain the steady state condition through the control loop connected with the Fuzzy Logic Controller (FLC). These loop defines the area control error (ACE) equal to zero and also reduces the load deviation towards the zero and performs the Load frequency control to steady state values.

Fuzzy logic has been widely applied in power electronic systems. Applications include speed control of dc and ac drives, feedback control of converter, off-line P-I and P-I-D tuning, nonlinearity compensation, on-line and off-line diagnostics, modeling, parameter estimation, and performance optimization of drive systems based on on-line search, estimation for distorted waves, and so on.

Area	Parameter	Without any controller	With PI Cont-roller	With Fuzzy Cont-roller
Multiarea(3)	Settling Time(sec)	Never settles down to steady state value	50sec	30sec

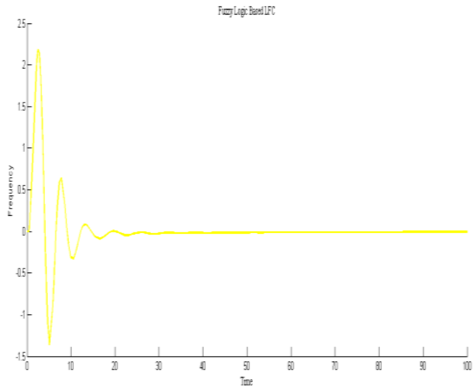


Figure 6.4 Fuzzy Output Waveform

6.3Comparison between PI and Fuzzy

VII CONCLUSION

The hydro thermal system considered in this study has three control areas. Each area has both thermal and hydro power plant. During load variations, the control area frequency and tie line power oscillates. It is damped using secondary PI controller along with speed governor. The gain values of PI controller tuned using FLC (fuzzy logic control) method, yields good response. Instead of fixed gain vales for PI controller, variable gain based on system condition is introduced using FGS. Better response is achieved while FGS is implemented. On analyzing the controller based on performance indices, it is found that variable structure fuzzy gain scheduling controller is found to be the best controller for multi source multi area power system

The future work of the project is to implement Particle Swarm Optimization (PSO) technical for the three area load frequency control (LFC) and to minimize the frequency deviation due to the load.

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