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Load Frequency Control in Two Area Power System Using Fuzzy Interface

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ABSTRACT: The load-frequency control (LFC), which employs speed control, is used to re-establish the balance between load and generation in each control region. The basic objective of LFC is to minimize the steady state error and transient deviations to zero beforehand. This paper explored LFC utilizing traditional Controllers and Fuzzy Inference System (FIS) for two area system. With the aid of the MATLAB/Simulink programme, the outcomes of the two controllers are compared. Results of comparisons between traditional controllers and fuzzy inference systems are shown.

KEYWORDS: Fuzzy Inference System (FIS), Conventional Controller, and Load Frequency Control

I. INTRODUCTION

Due to its growing demand, electricity generation is crucial nowadays. The system's dynamic behaviour is dependent on disturbances and adjustments to the operating point. The output of the system, which must have a steady frequency and maintain the scheduled power, determines the quality of the electricity produced in power plants. As a result, load frequency control (LFC) is crucial for the power system's ability to deliver dependable and high-quality electricity. Conventional controllers like PI, PD, and PID can provide control actions for a single operating condition, but in real-world situations, the parameters are constantly changing. Thus, it is challenging to set up the necessary improvements to achieve zero frequency deviation. Thus, it is essential to offer automatic correction.

In order to improve dynamic performance, a variety of control strategies have been used in the design of load frequency controllers. When comparing the many load frequency controller types, conventional controllers are the most prevalent and frequently used. Although conventional controllers are easy to implement, they produce significant frequency variation. To improve performance, the majority of state feedback controllers based on linear optimum control theory have been presented. Fixed gain controllers fail to deliver the optimal control performance under a variety of operating situations because they are built for nominal operating conditions. So, it is desirable to monitor operating circumstances and use up-to-date parameters to compute the control in order to maintain system performance close to its maximum. Self-adjusting gains settings in adaptive controllers have. It is well known, this load frequency management issue was what caused the Northern grid breakdown. This is a result of excessive grid usage in addition to excessive generation. It caused a blackout that affected all eight states in the practically entire Northern area. This was caused by the traditional controllers' faulty control actions, and despite the warnings being sent, some states continued to consume more electricity than they needed. In order to detect load changes and stabilise the frequency deviation, an adaptive control system is needed. In this research, a fuzzy inference system (FIS) technology is used to deliver an automatic control action. Results are presented after a comparison between the suggested controller and the traditional controller.

II. SINGLE AREA POWER SYSTEM

There are several categories used to categorise modern power systems. For instance, there are five regional grids in India, including the Eastern, Western, Northern, Southern, and North-Eastern grids. These regional areas are all commonly connected to their surrounding regions. Tie-lines are the transmission lines that link one area to its neighbouring territory. These tie-lines are used to distribute power between two places. Load frequency control, as the name suggests, controls the power flow between various locations while maintaining a consistent frequency.

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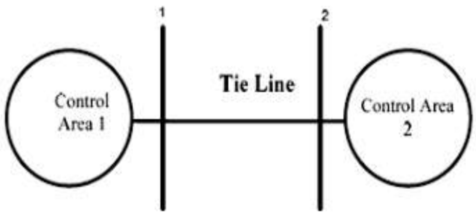
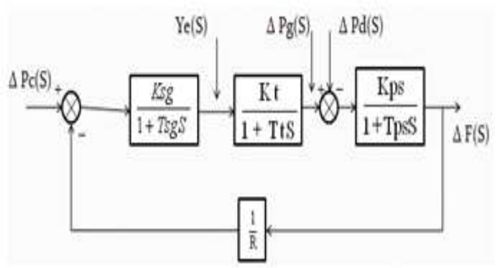


Inter Connected Power System

As long as "ΔP_{ref}" is set at zero, the system frequency will increase as the load reduces. In a



Single Area Power System

similar vein, frequency may drop as load rises. To ensure that Δf=0, it is important to keep the frequency constant. The transfer of power between the various tie lines is scheduled; for instance, area 'I' may export a predetermined amount of power to area 'j' while importing a second predetermined amount of power from area 'k'. Nonetheless, it is anticipated that area I will absorb any changes in load on its own, whether that be increased generation to supply additional load in the region or decreased generation when the area's load demand has declined. Therefore, area 'I' must continue to fulfil its obligations to areas "j" and

The load frequency control (LFC) has the following objectives:

- Hold the frequency constant (Δf=0) against any load change. Each area must have the capability to absorb any load change such that frequency does not deviate.
- Each area should maintain the tie-line power flow to its pre-specified value.

The first step in the Load Frequency Control is to form the area controller or (ACE) that is defined as

$ACE=(P_{tie}-P)+B_f\Delta f=\Delta P_{tie}+B_f\Delta$

Where P_{tie} and P_{sch} are the tie-line power and scheduled power through tie-line respectively and the constant B_f is called the frequency bias constant.

The change in the reference of the power setting $\Delta P_{ref\,i}$of the area I is then obtained by feedback of the ACE throughanintegral controlleroftheform

$\Delta P_{ref\,i}=-K_i\int ACE\,dt$ (2)

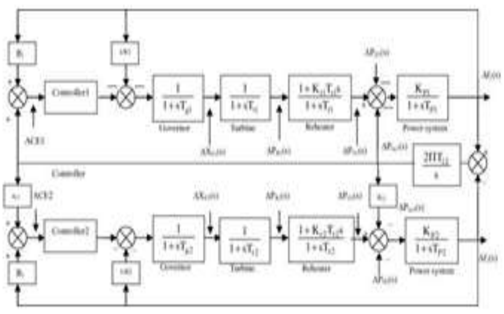
Where$K_i$istheintegralgain.

The ACE is negative if the net power flow out of an area is low or if the frequency has decreased or both. In this situation the generation must be increased to meet load demand. This can be achieved by increasing $\Delta P_{ref,i}$. This negative sign accounts for this inverse relation between $\Delta P_{ref,i}$ and ACE. The tie-line powerflow andfrequency of each area are monitored in its control center. Once the ACE is computed and $\Delta P_{ref,i}$ is obtained from Eq(2),commands are given to various turbine-generator controls to adjust their reference power settings.

Two single area systems are connected by tie-lines to form a two area power system. Making a mathematical model of the system is important before developing any control strategies. Conveniently, it is believed that an equivalent turbine, speed governing system, generator, and load may represent each control region. Figure 2 displays the block diagram for a single area power system.In a two-area power system, each individual area contains a number of generators that are closely connected together in order to form a coherent group, meaning that the power system's generatorsshould all react simultaneously to changes in load. A control region is one such coherent area where it is anticipated that the frequency would remain constant in both static and dynamic situations. Initially, the speed controlling system is in charge of managing load variations. But, in this system, a different controller (PID) is utilised once more to minimise the frequency variation. In one working state, the PI Controller may provide the optimal control action for frequency deviation. The PID Controllers fail to bring the frequency deviation when the operating range is wide. This difficulty is avoided by the Fuzzy Inference System (FIS).

III. TEO AREA LOAD FREQUENCY CONTROL

Two control loops are present in the traditional AGC design. The primary control loop regulates the frequency using the governor's self-regulating capabilities, however frequency variation is not completely eliminated. Additionally, the feedback control loop features a controller that, using traditional proportional integral control action, may eliminate the frequency deviation. The basic goal of feedback control is to maintain the system frequency and tie-line power flows at their predetermined values by restoring the balance between load and generation in each control region following a disturbance. Figure 3 depicts the load frequency control block diagram for a two-area linked power system



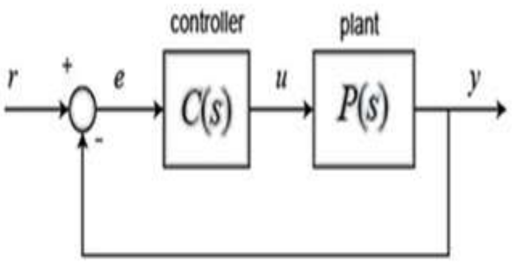
Two-Area Inter connected Power System

The shift in frequency in a single-area example is known as the ACE. When ACE is employed in an integral-control loop, the steady state error in frequency will be zero (i.e.,Δf_{SS}= 0). ACE is the linear combination of the frequency change and tie-line power change in a two-area example. In this situation, a second integrator loop for each region must be added in addition to the integral frequency loop to integrate the incremental tie-line power signal and feed it back to the speed changer inorder
to achieve the steady-state tie-line power zero (i.e. ΔP_{tie}= 0).

The requirements of the integral control action are:

- ACE must be equal to zero atleast one time in all10-minute periods.

Average deviation of ACE from zero must be within specified limits based on percentage of system generation forall10-minute periods.



IV. PID CONTROLLER

Conventional PID Controller on i-th Area
The control input U_i is constructed as follows:

$$U_i = -K_i\int_0^T ACE_i\,dt = -\int_0^T(\Delta P_{tie_i}+B_i\Delta F_i) \quad (3) \qquad (3)$$

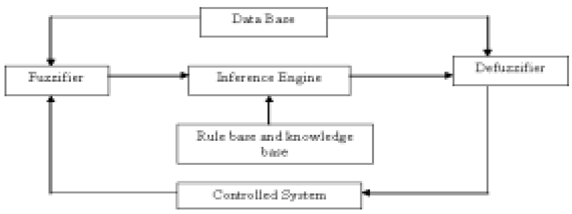
Taking the derivative of the equation yields

$$U_i = -K_i(ACE_i) = -K_i(\Delta P_{tie_i}+B_i\Delta F_i) \qquad (4)$$

The constants K_i(1, 2) are the gain of the integrator. It is observed that for decrease in both frequency and tie-linepower generation should decrease, i.e., if the ACE is negative, the speed-changer position decreases and hence the powergeneration should decrease, i.e., if the ACE is negative, then the area should increase its generation, so negative is assignedto the right-handside term.

V. FUZZY INTERFACE

The PID controller is the most widely used industrial controller due to its straightforward design and efficient operation. Yet, due to their linear design, traditional PID controllers are typically ineffective when controlling higher order, time delay, non-linear, complicated, uncertain, or systems with sophisticated mathematical models.



Structure of Fuzzy Logic controller

VI. SIMULATION AND RESULTS

a) simulation model for two-area load frequency control

Simulation block diagram of two area load frequency control, designed in simulation using Fig.5.1 and run the simulation in MATLAB with the help of parameters provided in table.1.and the simulation gives the results for change in frequency and tie line power with the change in load.fig.6 indicates the two-area load frequency control without any controller. with the 10 % change(increase) in load in area.1shows the effect not only on the frequency of area.1 but also it shows the impact on area.2 frequency and tie line power. there is some instability in both transient and steady state frequency response of area1,2 and tie line power Ptie1,2. Fig.6.1 shows the tie-line power having a greater number of oscillations due to sudden change in load

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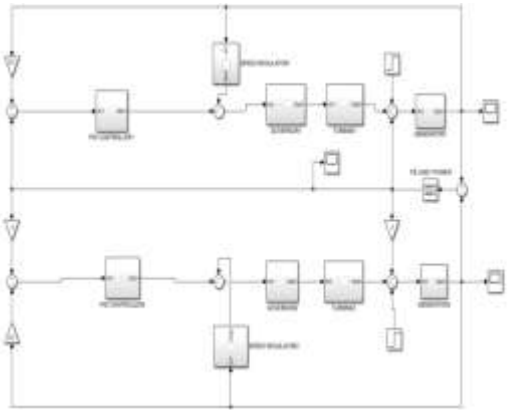
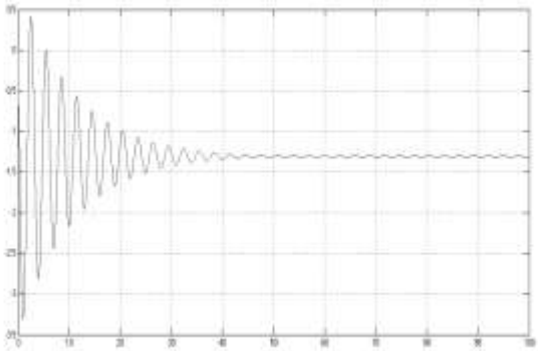


Simulink model of two area load frequency control with conventional PID controller

b) Simulation results without controller

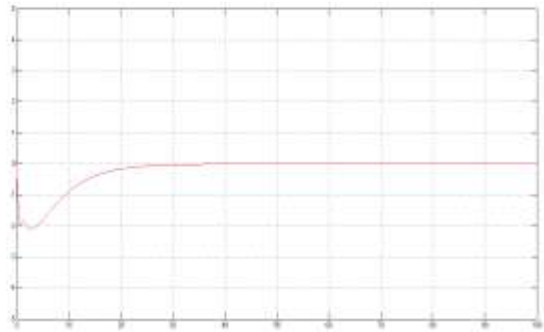
Due to sudden change in load in one of the control areas of 1% there will be corresponding change in the power system frequency that is deviations of system frequency from its normal steady state operating conditions. Figure 6.2 shows that large oscillations in its transient conditions and it have a steady state error of -1.378 without any controller



two-area load frequency control without controller

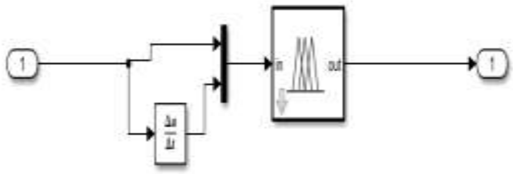
c) Simulation results with PID controller

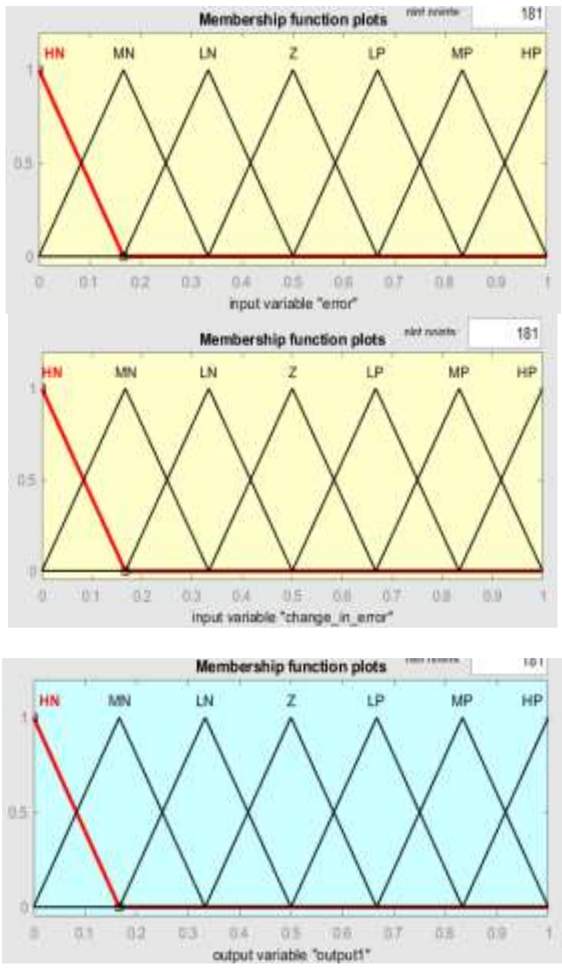
Figure 6.5 shows the response of two area load frequency control with PID controller which makes the steady state error is zero and also shows good control over the transient state that reduce the oscillations in transient conditions



Response of two area load frequency control with PID controller

d) Simulation of Two area load frequency Fuzzy controller





Fuzzy rule base membership functions

e) Fuzzy controller design

The most important things in fuzzy logic control system designs are the process design of membership functions for inputs, outputs and the process design of fuzzy **if-then** rule knowledge base. They are very important in fuzzy logic control. The basic structure of Fuzzy Logic Controller is given in Fig.5.6. Fortwo area LFC, frequency error (**E**) and change in frequency error (**CE**) are taken as the two inputs for the fuzzy controller and one output control input (**CI**). For this, a three-member as well as a seven-member rule base is devised. The rule base for seven membership functions is shown in Tables .

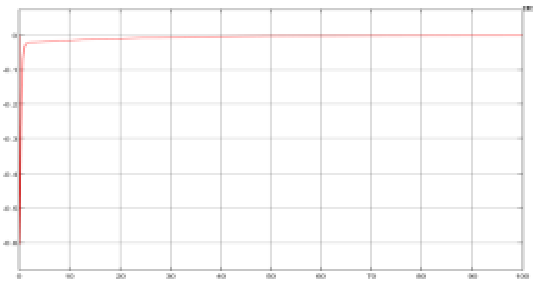
ACE ΔACE	HN	MN	LN	Z	LP	MP	HP
HN	HP	HP	HP	MP	MP	LP	Z
MN	HP	MP	MP	MP	LP	Z	LN
LN	HP	MP	LP	LP	Z	LN	MN
Z	MP	MP	LP	Z	LN	MN	MN
LP	HP	LP	Z	LN	LN	MN	HN
MP	LP	Z	LN	MN	MN	MN	HN
HP	Z	LN	MN	MN	HN	HN	HN

HN: High Negative, MN: Medium Negative, LN: Low Negative, Z: Zero, HP: High Positive, MP: Medium Positive, LP: Low Positive

The fuzzy logic based control system has been studied by simulation in order to validate the design and to evaluate the performance. Simulation result gotten by a fuzzy logic controller which gives good performance in a constant load case .When one need only design the FLC to provide control command. It is seen that FLC provides faster response and less overshoot. Fig.6.10. Shows the output response two area LFC.

f) Two Area load frequency control Results with FUZZY controller

fuzzy controller gives better response in both transient and steady state period



output response two area LFC with FLC

VII. CONCLUSION

The tie line power changes due to a sudden change (increase) in load, and two region load frequency control was modelled using MATLAB simulation in this research. Integral controllers are used to increase steady state response, which reduces oscillations in tie line power and ensures that steady state error is equal to zero. Transient oscillations are reduced via a derivative controller. The traditional PID controller, which is connected to the tie line in series, is the best controller since it eliminates steady state error and lessens transient tie line power oscillation. A new type of controller known as a fuzzy logic controller operates usingfuzzy logic membership functions, and as a result, both transitory.

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