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Fuzzy Tuned Pi Controller Based Automatic Load Frequency Control of Multi Area System

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ABSTRACT

Currently as there has been an increase in the interconnected systems as far as power systems are concerned. Load as well as power flow in tie-line are varying dynamically. So there is a need of robust control of system frequency as well as tie-line power flow system. This robust control could be achieved by the help of fuzzy logic controllers in the place of orthodox system using proportional, PI and PID controllers. This is due to the fact that gain constants in the case of conventional controllers remain same throughout, for changes in the load value. But Load can't be the same throughout, load deviates from time to time. So as to get rid of these disadvantages related to conventional controllers, a lot many schemes have been put forth in literature. With regard to this work, fuzzy logic base controller has been considered for problems pertaining to load frequency control. There queried rules are carried out with respect to the variation in load to diminish the error. In fuzzy logic controller, we take the help of triangular membership function in the formulation of the rule base, because triangular membership function gives easy way to make the rule base compared to other membership functions. Then simulation is done by using Matlab/Simulink software.

Key Words : load frequency control, fuzzy logic controller, PI and PID controllers

1. INTRODUCTION

Modern day power systems are divided into various areas. For example in India there are five regional grids, e.g., Eastern Region, Western Region etc. Each of these areas is generally interconnected to its neighboring areas. The transmission lines that connect an area to its neighboring area are called **tie-lines** . Power sharing between two areas occurs through these tie-lines. Load frequency control, as the name signifies, regulates the power flow between different areas while holding the frequency constant. As we have in that the system frequency rises when the load decreases if ΔP_{ref} is kept at zero. Similarly the frequency may drop if the load increases. However it is desirable to maintain the frequency constant such that $\Delta f=0$. The power flow through different tie-lines are scheduled - for example, area- i may export a pre-specified amount of power to area- j while importing another pre-specified amount of power from area- k . However it is expected that to fulfill this obligation, area- i absorbs its own load change, i.e., increase generation to supply extra load in the area or decrease generation when the load demand in the area has reduced. While doing this area- i must however maintain its obligation to areas j and k as far as importing and exporting power is concerned. A conceptual diagram of the interconnected areas is shown in

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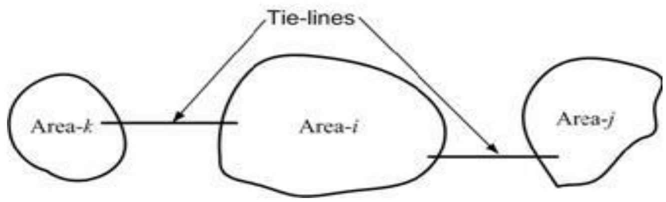
Fig.



Interconnected areas in a power system.

We can therefore state that the load frequency control (LFC) has the following two objectives:

- Hold the frequency constant ($\Delta f = 0$) against any load change. Each area must contribute to absorb any load change such that frequency does not deviate.
- Each area must maintain the tie-line power flow to its pre-specified value.

The first step in the LFC is to form the **area control error (ACE)** that is defined as

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

where P_{tie} and P_{sch} are **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

$$\Delta P_{ref,i} = -K_i \int \mathrm{ACE}\, dt$$

obtained by the feedback of the ACE through an integral controller of the form

where K_i is the integral gain. The ACE is negative if the net power flow out of an area is low or if the frequency has dropped or both. In this case the generation must be increased. 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 power flow and frequency of each area are monitored in its control center. Once the ACE is computed and $\Delta P_{ref,\ i}$ is obtained commands are given to various turbine-generator controls to adjust their reference power settings.

Load frequency control:

With many loads linked to a system in a power system, speed and frequency vary with the characteristics of the governor with variations in loads. No need to modify the setting of the generator if maintaining of constant frequency is not needed. When constant frequency is needed the turbine speed can be adjusted by varying the governor characteristic. Complications arise when 2 generating stations in parallel, are handling the variation in load. Chances of distribution of load in two systems are mentioned below:

Let both generating stations are interconnected through a tie line. If load varies at X or Y & A generation has to maintain the constant frequency, at that time it's known as **Flat Frequency Regulation.**

- ✓ Secondly where both X & Y have to maintain the constant frequency. It's known as **parallel frequency regulation.**
- ✓ Thirdly where frequency maintenance is done of a certain Area by its own generator & keeping constant the tie-line loading. It's called **flat tie-line loading control**.
- ✓ In **Selective Frequency control** individually system handles the variation in load itself & without interfering, beyond its limits, the maintenance of the other one in that group.
- ✓ In **Tie-line Load-bias control** all systems in the interconnection help in maintaining frequency no matter where the variation is created. It has a principal load frequency

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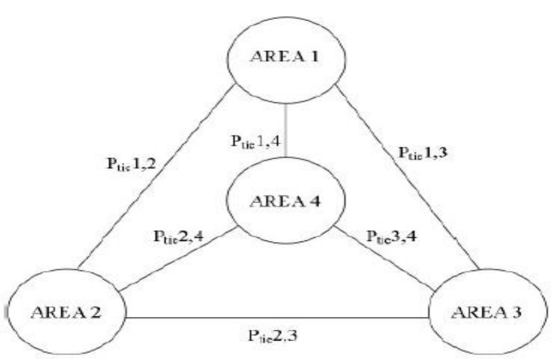
controller & a tie line plotter determining input power on the tie for proper control of frequency.

Multi Area System

Power systems have variable and complicated characteristics and comprise different control parts and also many of the parts are nonlinear . These parts are connected to each other by tie lines and need controllability of frequency and power flow. Interconnected multiple area power systems can be depicted by using circles. A simplified four area interconnected power system used in this study, each area can be represented as equivalent generating unit and interconnected through lossless tie-lines with some reactance. As simplified four-area interconnected power systems a four-area interconnected system block diagram is depicted. The system frequency deviation Δfi, the deviation in the tie-line power flow ΔPtie,i, load disturbance ΔPDi. The system parameter values are given in Appendix.



Frequency Control

The frequency of a system is dependent on the generated and consumed active power balance. In order to control the frequency at its target value, a certain amount of active power reserves is kept available to maintain the balance between the active power generation and consumption in case of disturbance. There are many different terms, definitions and rules concerning what frequency control reserves entail [10]. The general hierarchical classifications of frequency reserve services are: (i) frequency response, regulation, contingency reserve and load following in the NERC and, (ii) primary frequency control, secondary frequency control, tertiary frequency control and time control in the ENTSOE [11]. The ENTSOE has recently classified the frequency reserve services as frequency containment reserve, frequency restoration reserve and replacement reserve [12]. These frequency control reserves can be activated automatically and/or manually. Following a disturbance, the automatic fast controllers aim to stabilize the frequency and then to bring the frequency back to its target value. The manual controls are used to manage the contingencies and to restore the automatic control reserves, frequency and interchanges to their target values. These classifications are commonly taking into account the time scale decomposition of different control schemes. Likewise to the voltage control, the frequency control reserves can be

provided from the preventive and/or corrective control actions

Basic Controller Types

PID controllers use a 3 basic behavior types or modes: P - proportional, I - integrative and D - derivative. While proportional and integrative modes are also used as single control modes, a derivative mode is rarely used on it' s own in control systems. Combinations such as PI

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and PD control are very often in practical systems.

PI Controller:

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively.

However, introducing integral mode has a negative effect on speed of the response and overall stability of the system.

Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

PI controllers are very often used in industry, especially when speed of the response is not an issue. A control without D mode is used when:

a) fast response of the system is not required

b) large disturbances and noise are present during operation of the process

c) there is only one energy storage in process (capacitive or inductive)

d) there are large transport delays in the system

PID Controller

PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode). Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot is for the most part PID type controllers.

Effects of Coefficients:

Parameter	Speed of response	Stability	Accuracy
increasing K	increases	deteriorate	improves
increasing K_i	decreases	deteriorate	improves
increasing K_d	increases	improves	no impact

FUZZY LOGIC CONTROLLER

3.1.Introduction

Fuzzy set hypothesis and fuzzy rationale secure guidelines of a nonlinear plotting. Utilization of fuzzy sets gives a premise to a organized path for the requisition of indeterminate and inconclusive prototypes. Fuzzy controller is focused around a legitimate structure termed fuzzy rationale is very nearer in soul to human intuition and regular dialect than established intelligent systems. These days fuzzy rationale is utilized as a part of very nearly all parts of manufacturing and science. From those LFC is one. The primary objective of LFC in connected power networks is to secure the harmony among handling and utilization. In light of the multifaceted nature and multi-parameterized states of the power system, traditional controller strategies possibly will not give acceptable results. Then again, their strength

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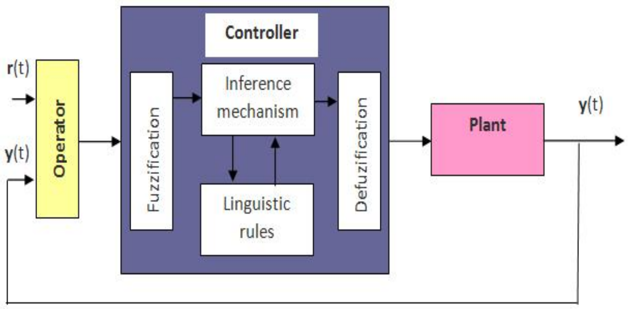
and unwavering quality make fuzzy controllers helpful in understanding an extensive variety of control issues. The fundamental constructing units of a Fuzzy Logic Controller are a fuzzification unit, a fuzzy rationale thinking unit, a learning base, and a defuzzification unit. It is the procedure to change the convinced fuzzy control movements to a fresh control movement.

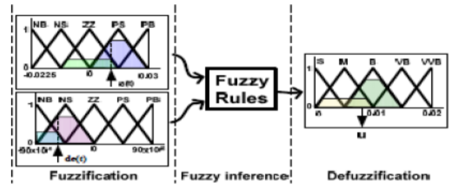


Design Of Fuzzy Logic Controller:

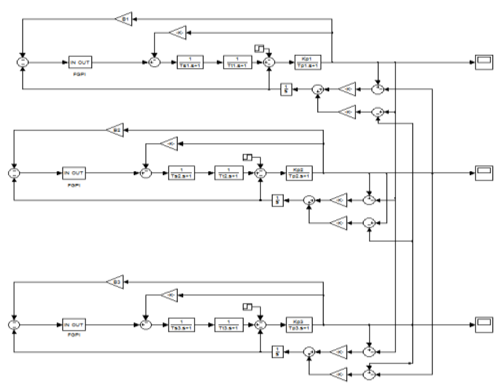
Assumptions in FLC system:

- The input and output variables can be witnessed and calculated.
- An acceptable result, not certainly a best, is adequate.
- A linguistic design may be created centered on the facts of a human expert.
- The human expert helps in modeling the linguistic model based on his knowledge

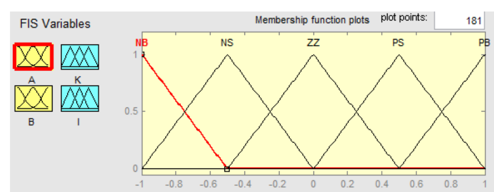
The basic building block of a fuzzy logic controller consist of four parts namely fuzzification of input followed by fuzzy reasoning and rule base to make perfect decisions. Then this block is being followed by knowledge base which defines all variables and parameters. The last block is the defuzzification block whose main function is to convert the fuzzy outputs to definite crisp values.



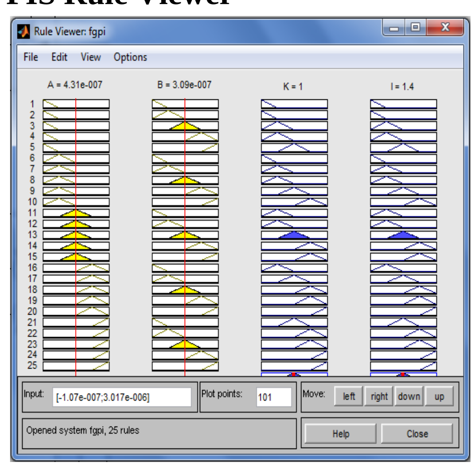
SIMULINK MODEL

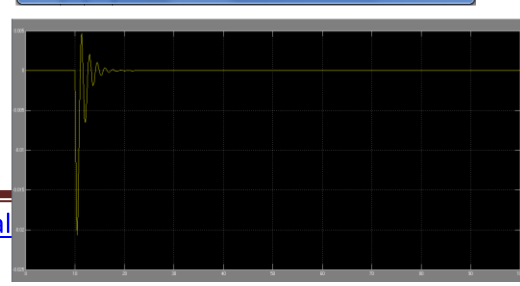


FIS Membership Function input



FIS Rule Viewer





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Output– Load Frequency Control

CONCLUSION

In this paper a new technique fuzzy logic PI controller is designed for automatic load frequency control of Multi area interconnected power systems. The controller performances Fuzzy logic PI approach is in work for a Load Frequency Control for Generation of Interconnected Power System. The proposed controller can handle the non-linearity's and at the same time faster than other conventional controllers. The effectiveness of the proposed controller in increasing the damping of local and inter area modes of oscillation is demonstrated in a two area interconnected power system. Also the simulation results are compared with a conventional other controller. The result shows that the proposed intelligent controller is having improved dynamic response and at the same time faster than conventional other (like as PI, PD) controller

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