International Journal of advancement in electronics and computer engineering (IJAECE)
Volume 3, Issue 10, January 2015, pp.371-375, ***ISSN 2278 -1412***

Overview Fuzzy Logic Approach for balancing Load frequency in Multi Area Power System

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Abstract- *In this paper, simulation evaluation is done to know the working of LFC by building models in SIMULINK which helps us to comprehend the principle behind LFC which include the challenge. Main function of fuzzy logic based frequency controller is to improve the dynamic performance of frequency that means to keep the frequency balanced during sudden load change in power system. Variations in load bring about drift in frequency and voltage which in turn leads to generation loss owing to the tripping and also blackouts. These drifts might be reduced to the smallest possible value by Fuzzy logic control method. Load cannot be constant when load varies with time but gain values of conventional controller are constant. Thus to overcome the conventional controller, fuzzy logic based controller is considered for load frequency control problem. The simulation result shows that the proposed FLFC can provides good damping and reduces the overshoot even in presence of the generation rate constraint.*

Keywords: *Load frequency control, Fuzzy logic based frequency controller (FLFC), Fuzzy logic control, Matlab.*

I. Introduction

In recent years, power system has more complicated and non-linear configuration. Therefore, tie-lines are used for various interconnected areas. Energy exchange between areas and inter area support during abnormal condition are provided through tie-lines [1-4] .These tie-lines have been observed with power fluctuations which result in increased system capacity[1]. Thus, load frequency control is more advanced controlled scheme which has been observed. In electrical power system, load-frequency (LF) control plays an important task for power system operation and design. Voltage and frequency controller are required to maintain generated power quality in order to supply constant voltage and frequency. Thus, the frequency is balanced or controlled by load-frequency controller. So many researches has been done over last few decades regarding load-frequency control of single and multi area power system [1-12].

Reliable and quality operation can be provided through LFC in interconnected areas of power system. The purpose of LFC is to regulate the frequency to a nominal value and to maintain the power between control areas of power system. Thus, many investigations in area of LFC problem have been reported and various control strategies has been employed in design of load frequency controller in order to achieve better dynamic performance [2-4]. And finally, Fuzzy-Logic approach is considered to be appropriate choice. Because Fuzzy-logic controller (FLC) can be simply expressed by set of rules that describes behavior of controller using linguistic terms. FLFC can be easily modified, simpler, quick and easy to implement.

II. Load- frequency (L-F) control

In recent years, power system is divided into various areas. These areas are interconnected to each other. 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 name itself signifies, regulates the power flow between different areas while holding frequency ConstantSystem frequency rises when the load decreases if reference power, ΔP_{ref} is kept at zero. Similarly, frequency may drop if, load increases. However, it is desirable to maintain the frequency constant such that $\Delta f=0$. Power flows through different tie-lines are scheduled. 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, to fulfill this obligation, area-I absorbs its own load change that is increase generation to supply extra load in the area or decrease generation when load demand in the areas has reduced. While doing this area-I must however maintain obligation to area j and k as far as importing and exporting power is concerned.

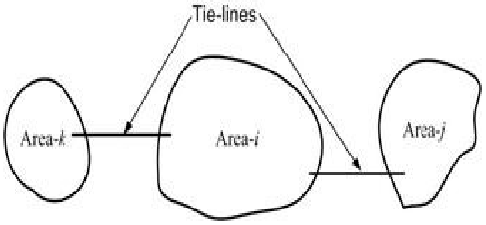

Fig.1.Interconnected areas in a power system

Load- frequency control (LFC) has two objectives:-

Hold the frequency constant ($\Delta f=0$) against any load change.

Each area must maintain the tie-lines power flow to its pre-specified value.

First step in the LFC is to form the area control error (ACE) that is defined as: -

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

Where, P_{tie} and P_{sch} are tie-line power and scheduled power through tie-line respectively and constant B_f is called the frequency bias constant.
The change in the reference of power setting $P_{ref,\,I}$ of the area-I is obtained by the feedback of ACE through an integral control of the form

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

Where, K_I is integral gain.
ACE is negative if 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 increased $\Delta P_{ref,\,I}$.

III. Literature overview

"Sheikh, M.R.I"In this paper, the influence of a Superconducting Magnetic Energy Storage (SMES) unit on the performance of the Automatic Generation Control (AGC) is investigated. In which, the self tuning Fuzzy PI Controller(FPIC) associated with the Automatic Generation Control (AGC) is proposed for the improvement of Load Frequency Control (LFC) in wind farm integrated large power system consisting of thermal and hydro power plants. The effects of the self tuning FPIC in AG Con SMES control is compared with that of optimized fixed gain PI controlled AGC.

"K. A. Ellithy, K.A. El-Metwally"This paper presents a novel approach for designing a decentralized controller for load frequency control of interconnected power areas. The proposed fuzzy logic load frequency controller (FLFC) has been designed to improve the dynamic performance of the frequency and tie line power under a sudden load change in the power areas. The effect of generation rate constraint (GRC) for both areas has been considered in the controller design. The proposed FLFC consists of two internal fuzzy logic controllers namely, the PD-like fuzzy logic controller and the PI-like fuzzy logic controller. The FLFC has been co-coordinated with the conventional integral controller.

"İsmail H. Altaş and Jelle Neyens2"A fuzzy logic based load frequency controller model for power systems is developed and simulated in this paper. The proposed simulation model is compared with the classical regulating systems in order to verify and show the advantages of the model and controller developed. The design process of the proposed fuzzy logic controller is given in detail step by step to show a direct and simple approach for designing fuzzy logic controllers in power systems.

"Rajesh Narayan Deo, Shiva Pujan Jaiswal, M. Venkateswarlu Naik"In this paper, a fuzzy logic controller technique is designed for automatic load frequency control of four-area interconnected power systems. The system dynamic performances are observed via using different controllers.

IV. Fuzzay logic controller

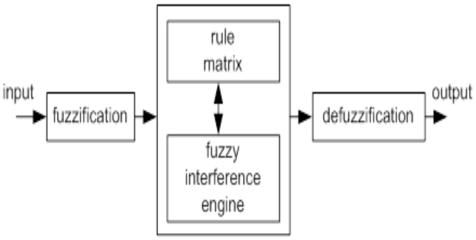

Fig.2. Fuzzay logic controller

Today control systems are usually described by mathematical models. Usually fuzzy logic control system is created from four major elements presented on Figure 2 fuzzification interface, fuzzy inference engine, fuzzy rule matrix and defuzzification interface.

V. Fuzzification Method

First phase of fuzzy logic proceeding is to deliver input parameters for given fuzzy system based on which the output result will be calculated. These parameters are fuzzified with use of pre-defined input membership functions, which can have different shapes. The most common are: triangular shape, however bell, trapezoidal, sinusoidal and exponential can be also used. Simpler functions will not require complex computing and will not overload the implementation. The degree of membership function is determined by placing a chosen input variable on the horizontal axis, while vertical axis shows quantification of grade of membership of the input variable. The only condition a membership function must meet is that it must vary between zero and one. The value zero means that input variable is not a member of the fuzzy set, while the value one means that input variable is fully a member of the fuzzy set.

VI. Rule Matrix

The rule matrix is used to describe fuzzy sets and fuzzy operators in form of conditional statements.
A single fuzzy if-then rule can be as follows

If *x* is A then *y* is Z,

Where, A is a set of conditions that have to be satisfied and Z is a set of consequences that can be inferred.
In rule with multiple parts, fuzzy operators are used to combine more than one input: AND = min, OR = max and NOT = additive complement.

The rule matrix is a simple graphical tool for mapping the fuzzy logic control system rules. It accommodates two or more input variables and expresses their logical product (AND or OR) as on It is often probable, that after evaluation of all the rules applicable to the input, we get more than one value for the degree of membership. In this case, the simulation has to take into consideration, all three possibilities, the minimum, the maximum or an average of the membership.

VII. Inference Mechanisms

Inference mechanism allows mapping given input to an output using fuzzy logic. It uses all pieces described in previous sections: membership functions, logical operations and if-then rules. The most common types of inference systems are Mamdani and Sugeno. They vary in ways of determining outputs.

VIII. Mamdani method

Below examples are based on two fuzzy control rules in the form of
R_1: if x is A_1 and y is B_1 then z is C_1
R_2: if x is A_2 and y is B_2 then z is C_2

Result: z is C, where x equals x_0 and y equals y_0.

The firing levels of the rules, denoted by α_i, i = 1, 2 are calculated by

$$\alpha_1 = A_1(x_0) \wedge B_1(y_0 \quad (3)$$

$$\alpha_2 = A_2(x_0) \wedge B_2(y_0 \quad (4)$$

The individual rule outputs are derived by

$$C_1'(\omega) = (\alpha_1 \wedge C_1(\omega \quad (5)$$

$$C_2'(\omega) = (\alpha_2 \wedge C_2(\omega \quad (6)$$

Then the overall system output is calculated by oring the individual rule outputs

$$C(\omega) = C_1'(\omega) \vee C_2'(\omega) = (\alpha_1 \wedge C_1(\omega)) \vee (\alpha_2 \wedge C_2(\omega \quad (7)$$

Finally, to obtain a deterministic control action, chosen defuzzification mechanism must be implemented.

IX. Sugeno method

Below examples are based on two fuzzy control rules in the form of

R_1: if x is A_1 and y is B_1 then z is $z_1 = a_1x_1+b_1y_1$
R_2: if x is A_2 and y is B_2 then z is $z_2 = a_2x_2+b_2y_2$

Result: z_0, where x equals x_0 and y equals y_0.

The firing levels of the rule are calculated in the same way as in Mamdani method, based on (3) and (4) equations. The individual rule outputs are calculated from the below relationships

$$z_1 = a_1 \cdot x_0 + b_1 \cdot y_0$$

Fuzzy Reasoning: -
It is based on theory of fuzzy sets and it encompasses artificial intelligence, information processing and theories from logic to pure and applied mathematics, like graph theory, topology and optimization. Theory of fuzzy sets was introduced in 1965.
The membership function $\mu_A(x)$ describes the membership of the elements x of the base set X in the fuzzy set A, whereby for $\mu_A(x)$ a large class of functions can be taken. Reasonable functions are often piecewise linear functions, such as triangular or trapezoidal function.The grade of membership $\mu_A(x_0)$ of a membership function $\mu_A(x)$ describes for the special element $x = x_0$, to which grade it belongs to the fuzzy set A.

$$\mu_A(x) = \begin{cases} 0, & x \le a \\ \frac{x-a}{m-a}, & a < x \le m \\ \frac{b-x}{b-m}, & m < x < b \\ 0, & x \ge b \end{cases}$$

This value is in the unit interval $[0,1]$. Of course, x_0 can simultaneously belong to another fuzzy set B, such that $\mu_B(x_0)$ characterises the grade of membership of x_0 to B

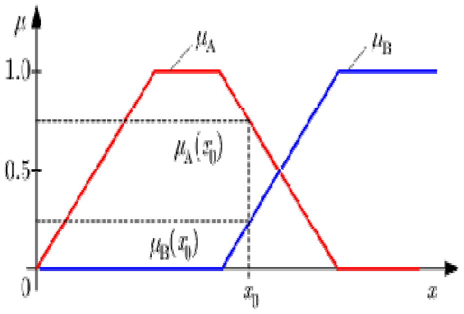

Fig.3:Fuzzy

Membership functions on Xrepresent fuzzy subsets of X. The membership function which represents a fuzzy set $\tilde{A}$is usually denoted by μ_A.For an element $x$of X, the value $\mu_A(x)$is called the *membership degree* of x in the fuzzy set $\tilde{A}$.The membership degree $\mu_A(x)$ quantifies the grade of membership of the element $x$to the fuzzy set $\tilde{A}$.

The value 0 means that $x$is not a member of the fuzzy set; the value 1 means that $x$is fully a member of the fuzzy set. The values between 0 and 1 characterize fuzzy members, which belong to the fuzzy set only partially

Properly designed power system should have: -

1It should supply the power everywhere the customer demands practically.
2It should always supply power.
3It should always supply the ever changing load demands.
4The supplied power should be of good quality.
5The supplied power should be economical.
6The necessary safety requirements should be satisfied.

Power delivered must satisfy certain minimal necessities with regards to supply quality. The superiority of power system can be decided when the system frequency must be kept around the specified value that is 50hz and the magnitude of bus voltage is maintained within prescribed limit around normal value.

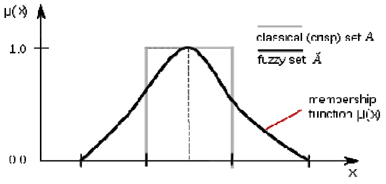

Fig.4

X. Conclusion

A fuzzy logic controller(FLC) coordinated with conventional integral controller has been proposed to damp out the deviations of the frequency and tie-line power for the interconnected power areas and also to keep the interchanged power at the scheduled value. The proposed FLC is more effective means for improving the dynamic performance of the two power area compared to the conventional integral controller. The proposed FLC controller still achieves good dynamic performance when the GRC is considered and ensures the stability of power areas for all load demand changes.

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