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A review on Load Frequency Control of a Multi-Area Power System with Fuzzy Logic Approach

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Abstract *– In the power system, the load varies all the time with respect to time which results with the frequency variation, therefore increasing in load frequency control problem.. The area for LFC's are planned based on accessibility of frequency variation of every area and tie-line power variation between areas. The load Frequency Control has important and essential issues in electrical power system. Thus, configurations of power system model, control strategies variety and a number of controllers are more effective, vigorous, adaptive and proficient. With the help of adaptive fuzzy, a new load frequency control for multi-area power systems is developed.*

Keywords*: adaptive fuzzy, LFC, load frequency control*

I. Introduction

Consists of turbines, generators governors and electrical loads. Ever since the frequency, the turbine and the governor are a feedback control system with an integrator, the power networks frequency is controlled as the intended constant value. The purpose of load frequency control (LFC) is to maintain the frequency of each control area in an organized power system and to order the exchanged tie-line power flows between neighboring control areas. The mismatch between the total generated power and the load demand in power system leads to random frequency variation and power interchanges between areas.This unevenness is to be corrected by load frequency control (LFC) system. The load frequency control (LFC) of a multi-area power system is the mechanism that balances between power generation and the demand. The load fluctuations are maintained by the frequency variation within satisfactory limits. Load Frequency Control (LFC) suppresses power system frequency variation and tie line power flow deviations to within prearranged values, consistent with intermittently varying loads and instability.

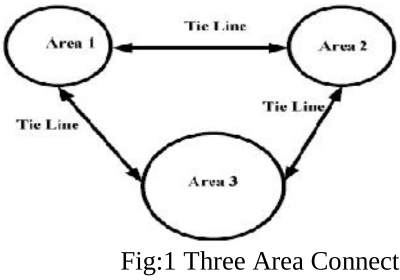

Fig:1 Three Area Connection

II. 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.

II.1 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.

II.2. 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.

II.3. Mamdani Method

Mamdani’s fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani [Mam75] as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes [Zad73]. Mamdani-type inference, as we have defined it for the Fuzzy Logic Toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. It's possible, and in many cases much more efficient, to use a single spike as the output membership function rather than a distributed fuzzy set. This is sometimes known as a *singleton* output membership function, and it can be thought of as a pre-defuzzified fuzzy set. It enhances the efficiency of the defuzzification process because it greatly simplifies the computation required by the more general Mamdani method, which finds the centroid of a two-dimensional function. Rather than integrating across the two-dimensional function to find the centroid, we use the weighted average of a few data points

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

$$\boldsymbol{\alpha_1 = A_1(x_0) \wedge B_1(y_0)} \qquad \textbf{(1)}$$

$$\boldsymbol{\alpha_2 = A_2(x_0) \wedge B_2(y_0)} \qquad \textbf{(2)}$$

The individual rule outputs are derived by

$$\boldsymbol{C_1(\omega) = (\alpha_1 \wedge c_1(\omega))} \qquad \textbf{(3)}$$

$$\boldsymbol{C_2(\omega) = (\alpha_2 \wedge c_2(\omega))} \qquad \textbf{(4)}$$

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

$$\boldsymbol{C(\omega)=C_1(\omega)\vee C_2(\omega)=(\alpha_1 \wedge c_1(\omega))\vee(\alpha_2 \wedge c_2(\omega))} \qquad (5)$$

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

II.4. Sugeno Method

Type systems support this type of model. In general, Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant. Sugeno output membership functions are either constant and linear.

In our paper we are using Mamdani inference system with triangular membership function.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 (1) and (2) equations. The individual rule outputs are calculated from the below relationships

$$z_1 = a_1 \cdot x_0 + b_1 \cdot y_0 \qquad (6)$$

III. Literature Review

Chuan-Ke Zhang, Jiang, L.; Wu, Q.H.; Yong He; Min Wu"delay-dependent robust load frequency control for time delay power systems"
In this paper, the usage of communication channels introduces time delays into load frequency control (LFC) schemes. Those delays may degrade dynamic performance, and even cause instability, of a closed-loop LFC scheme. In this paper, a delay-dependent robust method is proposed for analysis/synthesis of a PID-type LFC scheme considering time delays. The effect of the disturbance on the controlled output is defined as a robust performance index (RPI) of the closed-loop system. At first, for a preset delay upper bound, controller gains are determined by minimizing the RPI. Secondly, calculation of the RPIs of the closed-loop system under different delays provides a new way to assess robustness against delays and estimate delay margins. Case studies are based on three-area LFC schemes under traditional and deregulated environments, respectively. The results show that the PID-type controller obtained can guarantee the tolerance for delays less than the preset upper bound and provide a bigger delay margin than the existing controllers do. Moreover, its robustness against load variations and parameter uncertainties is verified via simulation studies.

SAXENA, S. HOTE, Y.V."load frequency control in power systems via internal model control scheme and model-order reduction". In this paper, the large-scale power systems are liable to performance deterioration due to the presence of sudden small load perturbations, parameter uncertainties, structural variations, etc. Due to this, modern control aspects are extremely important in load frequency control (LFC) design of power systems. In this paper, the LFC problem is illustrated as a typical disturbance rejection as well as large-scale system control problem. For this purpose, simple approach to LFC design for the power systems having parameter uncertainty and load disturbance is proposed. The approach is based on two-degree-of-freedom, internal model control (IMC) scheme, which unifies the concept of model-order reduction like Routh and Padé approximations, and modified IMC filter design, recently developed by Liu and Gao [24]. The beauty of this paper is that in place of taking the full-order system for internal-model of IMC, a lower-order, i.e., second-order reduced system model, has been considered. This scheme achieves improved closed-loop system performance to counteract load disturbances. The proposed approach is simulated in MATLAB environment for a single-area power system consisting of single generating unit with a non-reheated turbine to highlight the efficiency and efficacy in terms of robustness and optimality.

WEN TAN "unified tuning of pid load frequency controller for power systems via imc" A unified PID tuning method for load frequency control (LFC) of power systems is discussed in this paper. The tuning method is based on the two-degree-of-freedom (TDF) internal model control (IMC) design method and a PID approximation procedure. The time-domain performance and robustness of the resulting PID controller is related to two tuning parameters, and robust tuning of the two parameters is discussed. The method is applicable to power systems with non-reheated, reheated, and hydro turbines. Simulation results show that it can indeed improve the damping of the power systems. It is shown that the method can also be used in decentralized PID tuning for multi-area power systems.

"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.

IV. OVERVIEW OF LFC

It's incredible but so true that all the alternators runs at the same speed interrelated to a system and can be hundreds, thousands or even more .To understand how speed can be controlled, consider an isolated generator, supplying a local load, as shown in figure given below. There is two opposing torque which generator can experience; the mechanical torque (input), Tmech which is in the direction of rotation , and the other is Telect, in the opposite direction of rotation that acts to slow down the speed.

Both torques will be equal in magnitude and speed will remain constant In the steady state circumstance. When there is a change in electric load on the generator, equilibrium between the mechanical torque (Tmech) and the electrical torque (Telect) is disturbed, which results in speed variation. This continues until system attains a new equilibrium point. For a lossless system, the relationship between imbalance and speed can be expressed as,

$$\text{Pmech} - \text{Pelect} = \text{M} \qquad (7)$$

where, Pmech is mechanical power input to the turbine, Pelect is electrical power output of the generator, ωs is rotational speed of the rotor and M is inertia coefficient.

V. Fuzzy logic controller

Fuzzy logic is a thinking process or problem-solving control methodology incorporated in control system engineering, to control systems when inputs are either imprecise or the mathematical models are not present at all. Fuzzification is process of making a crisp quantity into the fuzzy. They hold significant improbability. If the form of improbability happens to arise because of ambiguity, or vagueness, then the variable is probably fuzzy and can be represented by a membership function. Defuzzification is the conversion of a fuzzy quantity to a crisp quantity, just as fuzzification is the conversion of a precise quantity to a fuzzy quantity.

VI. Conclusion

This paper presents a new load frequency control for multi-area power system . Load frequency control has significant issue since the association of first power system. Major objectives of LFC includes following the changes in load demands and amendable frequency. The tie line power inter-changes to specified values maintained by Specific LFC methods . This paper has reviewed key fiction of pre-deregulation scenario in the area of LFC .the four category, namely, Tie-Line Bias Control, Optimal Control, Multi-level and Decentralized Control, and Adaptive Control described the most important features of various LFC . by using current research outcomes consequence of these methods has been established in post-deregulation.

REFERENCES

[1] P. Kundur, "Power System Stability and Control," New York, USA: McGraw-Hill, 1994.

[2] H. Saadat, " Power System Analysis," New York, USA:McGraw-Hill,1999.

[3] D. J. Lee, and L. Wang,"Small-Signal Stability Analysis of an Autonomous Hybrid Renewable Energy Power Generation/Energy Storage System Part I:Time-Domain Simulations," IEEE Transactions on Energy Conversion, vol. 23, no. 1, pp. 311-320, March 2008.

[4] P. K. Ray, S. R. Mohanty, and N. Kishor,"Small-Signal Analysis of Autonomous Hybrid Distributed Generation Systems in Presence of Ultracapacitor and Tie–Line Operation," Journal of Electrical Engineering, vol.61, no.4, pp.205-214, 2010.

[5] T. Senjyu, T. Nakaji, K. Uezato, and T. Funabashi,"A Hybrid Power System Using Alternative Energy Facilities in Isolated Island," IEEE Transactions on Energy Conversion, vol. 20, no. 2, pp. 406-414, June 2005.

[6] M. A. Sofla, and R. King,"Control Method for Multi-Microgrid Systems in Smart Grid Environment—Stability, Optimization and Smart Demand Participation," IEEE PES, Innovative Smart Grid Technologies (ISGT), pp. 1-5, Date 16-20 January, 2012.

[7] M. Matsubara, G. Fujita, T. Shinji, T. Sekine, A. Akisawa, T. Kashiwagi, and R. Yokoyama,"Supply and Demand Control of Dispersed Type Power Sources in Micro Grid," Proceedings of the 13th International Conference, Intelligent Systems Application to Power Systems, pp.67 – 72, 2005.

[8] X. Li, Y. Li, X. Hanb, and D.Hui,"Application of Fuzzy Wavelet Transform to Smooth Wind/PV Hybrid Power System Output with Battery Energy Storage System," The Proceedings of Internation Conference on Smart Grid and Clean Energy Technologies, vol. 12, pp .994–1001, 2011.

[9] X. Li, D. Hui, L. Wu, and X. Lai,"Control Strategy of Battery State of Charge for Wind/Battery Hybrid Power System,"IEEE International Symposium on Industrial Electronics (ISIE), pp. 2723 – 2726, 2010.

[10] N. J. Gil, and J. A. P. Lopes, "Hierarchical Frequency Control Scheme for Islanded Multi-Microgrids Operation," in IEEE Lausanne Power Tech Lausanne, pp.473-478, 2007