A Fuzzy Controller for a Dynamically Multivariable Nonlinear Coupling System

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Abstract- This paper presents a novel methodology for designing an fuzzy controller for a dynamically multivariable nonlinear coupling system. One controller with constant gain for different operating points may not be sufficient to guarantee satisfactory performance for Interconnected Power System "IPS". Therefore, the knowledge-based fuzzy controller is proposed either to cope with the operating conditions or to remove any fixed mode. The fuzzy logic control utilizes the error and the change of error as fuzzy linguistic inputs to regulate the system performance. The proposed programs have been developed to simulate the dynamic behavior of the IPS. The new controller uses only the available information of the input-output for controlling the frequency deviation and the tie line performance. The objective of the Load Frequency Control (LFC) is to maintain the scheduled frequency and scheduled tie-line power in a normal mode of operation, during the small perturbation in operating conditions

Key words: Fuzzy Logic Control “FLC”, Load Frequency Control “ LFC”. Area Control Error “ ACE”. Interconnected Power System “IPS”, *MATLAB Simulink*

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List of Symbols:

i	Subscript for area i
ΔF_i	Frequency deviations
ΔX_{ei}	Incremental displacement of main piston
ΔP_{gi}	Incremental change in turbine power
$\Delta P_{tie,I}$	Incremental change in tie line power
$\Delta P_{d,I}$	Incremental change in load Demand
T_{ij}^0	Synchronizing coefficient between subsystems i,j
$\Delta P_{c,I}$	Incremental change in speed changer position
P	Positive label
N	negative label
Z	Zero Label

1. Introduction

A widely recognized goal of artificial intelligence is the creation of artifacts, usually software programs that can emulate human in their ability to reason symbolically. Intelligent control techniques comprise knowledge based expert or fuzzy control. It uses knowledge representation and reasoning at the heart of any system that reflects intelligence. Intelligent systems represent a combination of technologies that attempt to parallel or replicate human behavior within specific and narrowly defined contexts. Intelligent systems, in comparison, are flexible, and adaptive in that they draw on knowledge and the power of association and inference to steer the direction of a running program toward useful results.

Some characteristics of intelligent systems are: intelligent systems behave logically, solve complex problems responsive and adaptive, make effective use of existing information and user-friendly and highly interactive [1-6]. Emergence of a new advanced technology is intimately dependent on the connection between artificial intelligence and human though. This in turn, would require computers to understand human’s language.

This paper presents a novel methodology for designing a fuzzy controller for a dynamically interconnected electric power system. The proposed control scheme is applied to a two-area power system provided with both hydraulic and thermal turbines. This type of knowledge is usually expressed in the form of linguistic rules [4]. This paper is organized as follows, the second section describes the power system control problem,. The third section is devoted to discuss the fuzzy control scheme. The fourth section is concerned with the design of the proposed fuzzy control scheme. Finally the last section with the analysis of simulation, and the conclusion.

2. Power System Control

Load Frequency Control “LFC” sometimes, called Automatic Generation Control “AGC” is a very important aspect in power system operation and control for supplying sufficient and reliable electric power with the desired quality. LFC is a very important factor in power system operation. It aims at controlling the output power of each generator to minimize the transient errors in the frequency and thie-line power deviations and to ensure its zero steady state errors [5,6].

LFC generally involves several designed power areas within integrated power grids with each area responsible for controlling its Area Control Error ‘ACE”[3,4].

A two area interconnected power system model is developed. LFC of IPS” relies on an operating schedule, that, is usually prepared all day. The problem of the LFC of an IPS can be expressed mathematically as follows [5,8]

$$X = [X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8]$$

$$= [\Delta F_1, \Delta X_{g1}, \Delta Pg_1, \Delta F_2, \Delta X_{g2}, \Delta Hg_2 \Delta Pg_2, \Delta P_{tie1,2}] \quad (1)$$

$$U = [U_1, U_2, U_3, [U_4]$$

$$= [\Delta P_{c1}, \Delta P_{d1}, \Delta Pc2, \Delta P_{d2}] \quad (2)$$

The functional block diagram of two-area Hydro-Thermal IPS is shown in Fig.1 . Power deficits may be pure active , pure reactive , or combined. Any of these deficits affects the frequency of the system either directly.

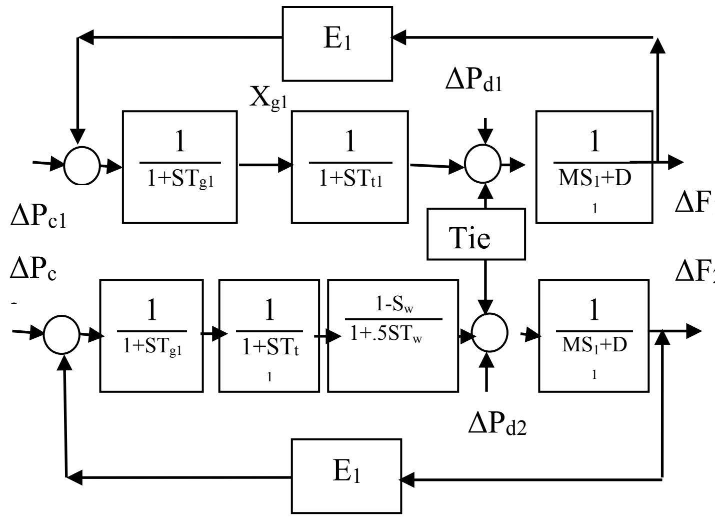

Fig.1 Block diagram of Hydro-Thermal Interconnected power system

The interlinking of the various areas in case of a two-area system is though the tie-line power exchange. Changes in tie-line power flows affected the power balance in corresponding areas as shown in Fig.2

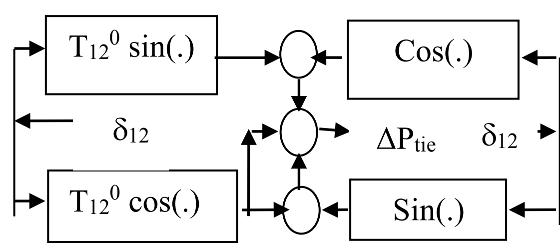

Fig.2 Tie -Line Power Exchange

The incremental tie-line power is

$$\Delta P_{tie1,2} = T_{12}^{0} \sin(\delta_1^0 - \delta_2^0) \cos(\Delta\delta_1^0 - \Delta\delta_2^0) - T_{12}^{0} \sin(\delta_1^0 - \delta_2^0) + T_{12}^{0} \cos(\delta_1^0 - \delta_2^0) \sin(\Delta\delta_1^0 - \Delta\delta_2^0) \quad (3)$$

I/p

3. Fuzzy Control Scheme

In general, the control engineer’s knowledge of the system is based on expertise, intuition, knowledge of the system’s behavior. Therefore, the main objective of the fuzzy control scheme is to replace an expert human operator with a fuzzy rule-based control system. The fuzzy logic controller comprises three stages namely fuzzifier, rule-based assignment tables and the defuzzifier [1-4].

A fuzzy system usually takes the form of an iteratively adjusting model. In such a system, input values are normalized and converted to fuzzy representations, the model's rule base is executed to produce a consequent fuzzy region for each solution variable, and the consequent regions are defuzzified to find the expected value of each solution variable [8-11].

A fuzzy logic system not only adjusts to time, or process phased conditions, but also changes the supporting system control, that is, an adaptive system modifies the characteristics of the rules [1-4,7, 9,10,14].

4. Fuzzy Control Algorithm

In this section, a systematic method is given to help the designer getting the best of reasoning algorithm that works well with the application required. The fuzzy logic controller proceeds as follows to evaluate the desired output signal, as shown in Fig.3.

Firstly, input variable are normalized, then the membership function of the fuzzy logic controller output signal is determined by linguistic codes, finally, the numerical value of the adaptive fuzzy logic controller output signal corresponding to a specific linguistic code is determined as shown in Fig.4.

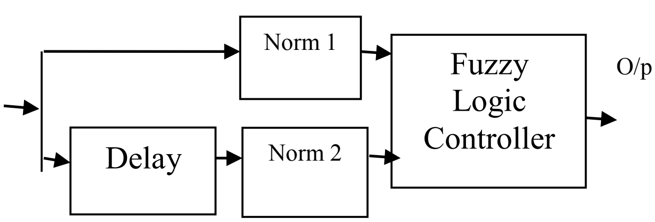

Fig. 3 The Structure of Fuzzy Logic Controller

The proposed rules depend on the following concepts [12-14] :

- The fuzzy controller maintains the output value, when the output value is set value and the steady state error changes is zero

- Depending on the magnitude and signs o frequency error and frequency error changes, the output value will return to the set value.

The error "e" and the error change " Δe" are defined as a difference between the set point value and the current output value as shown in table-1

$$e(k) = \Delta P_r^0(k) - \Delta P_c^0(k)$$
$$\Delta e(k) = e(k) - e(k-1) \quad (4)$$

That is,

$$\Delta P_r^0(k) = \Delta P_r^0(k-1)$$

Table 1 Linguistic variables

		$\Delta e(t)$		
		N	*Z*	*P*
$e(t)$	*N*	*S*	*M*	*S*
	Z	*M*	*B*	*M*
	P	*S*	*M*	*S*

***N*-negative, *Z*-zero, *P*-positive**
***S*-small, *B*-big, *M*-medium**

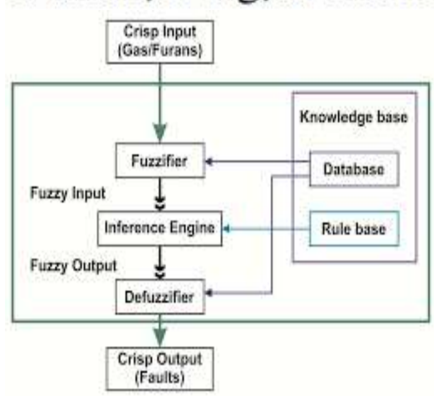

Fig.4 The Internal Structure of Fuzzy Logic Controller

This assumption is also satisfied in most cases:

Case (1)

$e(k) < 0$ and $\Delta e(k) > 0$

$\Longrightarrow \Delta P_r^0(k) < \Delta P_c^m(k)$

and $\Delta P_c^m(k) > \Delta P_c^m(k)$

Case (2)

$e(k) > 0$ and $\Delta e(k) < 0$

$\Longrightarrow \Delta P_r^0(k) > \Delta P_c^m(k)$

and $\Delta P_c^m(k) < \Delta P_c^m(k$

Where

- $\Delta P_r^m(k)$ is the reference of the fuzzy logic controller at k-th sampling interval
- $\Delta P_c^m(k)$ is the fuzzy logic controller signal at k-th sampling interval
- $e(k)$ is the error signal
- $\Delta e(k)$ is the error change signal

5. Simulation Results

In the case of two mixed area interconnected power system (TMAIPS), the system parameters are given as follows.

AREA -1 THERMAL AREA
M=0.04: D=0.01 : T_g=0.5 : E=0.03

AREA -2 HYDRAULIC AREA
M=0.03:D=0.008:T_g=1.2:T_T=0.5:
T_w=0.5: E=0.13

TIE-LINE POWER
T_{12}= 0.02701

In the case, where area 1 is subjected to a step load change and the area 2 is disturbance free. It can be seen that, the proposed fuzzy logic controller gives good performance shown in Fig (5).

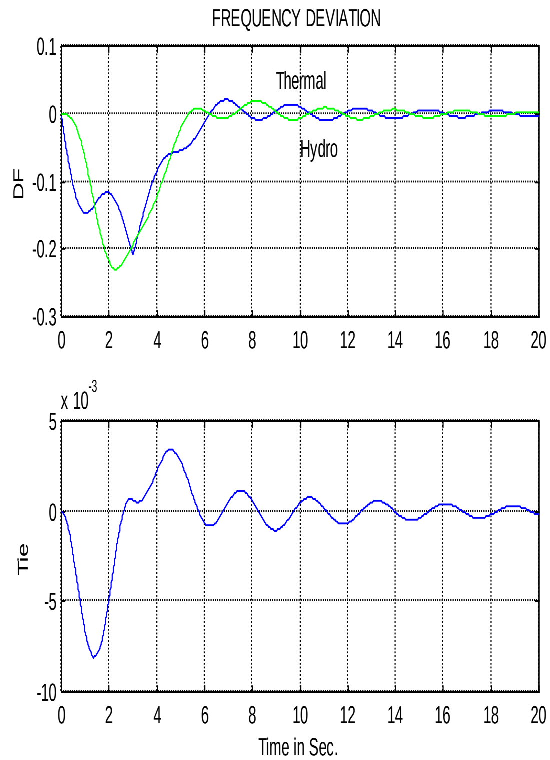

Fig.5 Frequency Deviation of hydraulic and thermal Interconnected Power Systems

6. Conclusion

In this paper, the solution of the tie-line control problem, and the problem of the load frequency control of interconnected power systems were discussed. The paper presents a fuzzy logic control strategy to ensure excellent study and guarantees the operation of interconnected power system. Simulation results show that the control performance can be obtained.

Therefore with the steady state analysis the performance of the system for specified operating point can be investigated.

Finally, we can conclude that the analysis of the operational characteristics resulted in key findings enabling a further derivation of control algorithms and examination of the fuzzy logic controller under dynamic operating conditions.

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