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Load Frequency Control Using PID and Fuzzy Logic Control for Multi Area Interconnection System

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Abstract: Load frequency Control is very important in the power system operation and control for supplying sufficient and reliable electrical power with good quality. The load demand should match the power generation. If there is any imbalance leads to a load frequency problems. In general, as the speed of the machine depends on the frequency, any deviation in the frequency may lead to mal-operation of the system. So load frequency control is the key problem in the power system. For specified power rating of the machine the voltage should maintain constant otherwise the system insulation may get damage. The controllers are set for a particular operation condition and they take care of small changes in load demand without frequency and voltage exceeding the prescribed limits. With the passage of time, as the change in load demand becomes large, the controllers must be reset either manually or automatically. In modern power system multi area inter connected systems are used for more reliability and economic purpose. In this paper using four areas for inter connected systems the frequency problems can be effectively decreased by using fuzzy logic controller with either of the 3, 5 or 7 membership functions. Here this fuzzy logic controller action also compared with automatic generation control and PID controllers also. By using fuzzy logic controller the frequency error, settling time, peak overshoot, under overshoots are effectively reduced.

Keywords: Frequency error, multi area inter connection, Automatic Generation Control (AGC), Fuzzy logic controller, PID.

I. INTRODUCTION

Power system operation considered so far was under condition of steady load .However, both active and reactive power demands are never and they continually change with the rising or falling trend. Steam input to turbo-generators (or water to hydro – generators) must, therefore be continuously regulated to match the active power demand, failing which the machine speed will vary with consequent change in frequency which may be highly undesirable (maximum permissible change in power frequency is ±0.5 Hz). Also the excitation of generations must be continuously regulated to match the reactive power demand with reactive generation, otherwise the voltage at various system buses may go beyond the prescribed limits. In modern large interconnected system, manual regulation is not feasible and therefore automatic generation and voltage regulation equipment is installed on each generator. In power system operation and control the load is varying continuously and randomly. The varying of load may cause Change in real and reactive powers. That means the real and reactive power demands are continuously varying and never steady. If active and reactive powers are changes that may are cause change in system frequency and voltages. But for the successful operation of the system the frequency and voltage should be maintain constant at their normal values The system frequency and voltage are maintain at their normal values by monitoring the load variations and taking suitable control action, to match the real and reactive power generations with load demand at the losses in the system at that time. The system frequency is indirectly depends upon the real power demand ,because increasing load on generation unit then more amount of real power is to be supplied. Which is immediately received from the kinetic energy (K.E) power in rotating part, thereby reducing the K.E of angular velocity or speed of the machine? The frequency at the system is directly depends upon the speed of the machine

f=P.Ns/120.
f-----system frequency
Ns----synchronous speed
P------number of poles in the machine

For the maintain of constant frequency the change in speed is sensed by a speed governing mechanics and control the position at inlet valve to the prime mover there by controlling the stem water supplied to the turbine. The system voltage is mainly controlled by the reactive power balanced in the system. The excitation of generator must be continuously regulated to match the reactive power demand with reactive power generation otherwise the voltage at various systems may go varying in the large interconnected system. In olden days the frequency and voltages are controlled manually. But due to manual operations the control action is very slow or it takes more (10 to 15 sec) time which is much enough for causing damage to the equipment. For the improvement of speed control PID controller is introduced. By using PID controller the control action is improved. For further control fuzzy logic controllers are used.

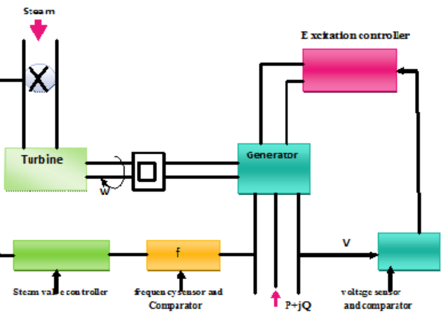

Fig .1 schematic diagram of load frequency and excitation voltage regulators of a turbo – generator

II. INTERCONNECTED POWER SYSTEMS

Modern day power systems are divided into various areas. For example in iraq , there are three regional grids, e.g. north Region, middle Region and south Region. 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. Two single area power systems are connected through a tie line in order to form an interconnected power system. The main advantage of interconnected power system is to attain the load demand. The system frequency rises when the load decreases if ΔP is kept at zero. Similarly the frequency may drop if the load increases. However it is desirable to maintain the frequency constant such that Δf=0. The power flow through different tie-lines is scheduled.

III.FUZZY LOGIC CONTROLLER

Fuzzy logic is another form of artificial intelligence. Fuzzy logic has been recently applied in process control, modeling, estimation, identification, diagnostics, stock market, prediction, agriculture, military science and so on. Fuzzy logic, unlike Boolean or crispy logic, deals with problems that have vagueness, uncertainty, imprecision or qualitative ness. In convention set theory based on Boolean logic, a particular object or variable is either a member (logic 1) of a given set or it is not (logic 0). On the other hand, in fuzzy set theory based on fuzzy logic, a particular object has a degree of membership in a given set which may be anywhere in the range of 0 to 1. The basic property like union (OR), intersection (AND) and complement (NOT) of Boolean logic are also valid for fuzzy logic. In the fuzzy logic system three main stages are there. They are

1). Fuzzification interface 2). Rules base analysis
3). Defuzzification module

For LFC the process operator is assumed to respond to variables error (e) and change of error (ce). The variable error is equal to the real power system frequency deviation (Δf). The frequency deviation Δf is the difference between the nominal or scheduled power system frequency and the real A FL based controller consists of three sections namely fuzzifier power system frequency., rule base, and defuzzifier as shown in Fig. 2 Two input signals, the main signal and its change for each sampling, to the FL controller are converted to fuzzy numbers first in fuzzifier. Then they are used in the rule table to determine the fuzzy number of the compensated output signal. Finally, the resultant united fuzzy subsets representing the controller output are converted to the crisp values.

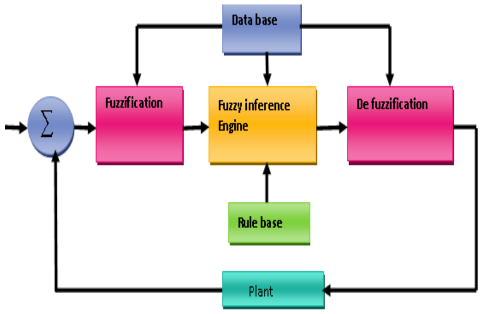

Fig.2 Structure of fuzzy logic controller

The FL based controller is designed to act as an integrator controller, such that the resultant incremental output Δu(k) is added to the previous value u(k-1) to yield the current output u(k).

A. Fuzzification

Fuzzification means change of crisp logic to fuzzy logic. In the fuzzy logic the frequency error (e) and change of frequency error (ce) can be split into 5 or 7 or 9 parts. These splitting parts ranges are arranged with the triangular member ship functions (MF).

B. Rules Base Analysis

The output membership grades for different fuzzy sets are derived by Zadeh’s AND and OR rules from the rule table.

TABLE 1: THE SIGNS OF BASIC CONTROL

	I	II	III	IV	V	VI	VII	VIII	IX	X
e	+	0	-	-	0	+	+	-	+	0
Δe	-	-	-	+	+	+	-	0	0	0
Δu	+	-	-	-	+	+	+	-	+	0

Table 1 show that each one of e, Δe , and Δu has three different options for the signs to be assigned. They are either positive or negative if not zero. Keeping in mind these three options, which are represented by three fuzzy sets namely positive (P), negative (N), and zero (Z),
For designing the rule base (table 4.2) for tuning the integral controller the following important factors have been taken into accounts IF e (k) is Negative Big AND Δe (k) is Negative Big THEN output is Negative Big

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IF e(k) is Negative Big AND Δe (k) is Negative medium THEN output is Negative Big Fuzzy logic controller has been used in both the thermal - thermal and hydro - thermal and thermal –wind inter connected areas. Attempt has been made to examine with five number of triangular membership functions (MFs) which provides better dynamic response with the range on input (error in frequency deviation and change in frequency deviation) i.e. universe of discourse is - 0.25 to 0.25. The number of rules is 25. The dynamic response are obtained and compared to those obtained with conventional integral controllers [3]. Further, several inputs have been tried out and dynamic responses are examined in order to decide suitable inputs to the fuzzy logic controller (FLC).

Model 1: 5 MF with 25 Rules

In a fuzzy scale, each membership functions of five linguistic states of triangular type are mapped into the values of Negative Large (NL), Negative Small (NS), Zero Error (ZE), Positive Small (PS) and Positive Large (PL). With the 5MFs 25 rules are formed and are applied to the system. The response curves of Δf1 and Δf2 shows more stability. It shows typical hydro-thermal area like behaviour with fast settling time.

TABLE 2: FUZZY RULES FOR 5 MEMBERSHIP FUNCTION

Variable	NL	NS	ZE	PS	PL
NL	NL	NL	NS	NS	ZE
NS	NL	NL	NS	ZE	ZE
ZE	NS	NS	ZE	PS	PS
PS	ZE	PS	PS	PL	PL
PL	ZE	ZE	PS	PL	PL

Model 2: 7 MF with 49 Rules

In a fuzzy scale , each membership functions are divided into seven linguistic stages of triangular type and are given as Negative Large (NL) , Negative Medium (NM) , Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM) and Positive Large (PL). By using these 7 MF's 49 governing rules are formed and applied to the system

TABLE 3: FUZZY RULES FOR 7 MEMBERSHIP FUNCTION

Variable	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NM	NS	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PS
PS	NL	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
ZE	PS	PM	PL	PL	PL	PL	PL

C. Defuzzification

The center of gravity (COG) defuzzification method is used to compute the output control (u) as following U = Nu (Σ im Wi Yi) / (Σ im Yi) Where wi is the grade of ith output MF, yi is the output label for the value contributed by the ith MF , and m is the number of contributions from the rules.

IV. PID CONTROLLER

A Conventional PID controller is most widely used in industry due to ease in design and inexpensive cost. The PID formulas are simple and can be easily adopted to corresponding to different controlled plants but it can"t yield a good control performance if controlled system is highly order and nonlinear. The PID controller is a combination of the PI and PD controllers. The PD control, as in the case of the lead compensator, improves the transient-response characteristics, improves system stability, and increases the system bandwidth, which implies fast rise time. PID is a lag-lead compensator. PI control action and PD control action occur in different frequency regions. The PI control action occurs at the low-frequency region and PD control action occurs at the high-frequency region. The PID control may be used when the system requires improvements in both transient and steady-state performances. Figure 3 shows a PID controller of a plant. The process of selecting the controller parameters

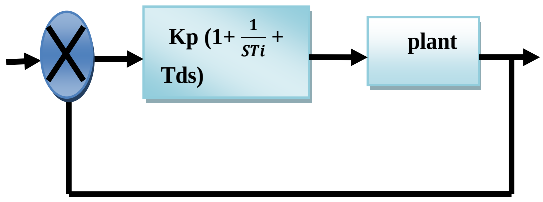

Fig. 3 PID Control of Plant

to meet given performance specifications is known as controller tuning. Ziegler and Nichols suggested rules for tuning PID controllers (meaning to set values Kp, Td and Ti) based on experimental step responses or based on the value of Kp, that results in marginal stability when only proportional control action is used. Such rules suggest a set of values of Kp, Td and Ti that will give a stable operation of the system. However, the resulting system may exhibit a large maximum overshoot in the step response, which is unacceptable. In such a case we need series of fine tunings until an acceptable result is obtained. In fact, the Ziegler-Nichols tuning rules give an educated guess for the parameter values and provide a starting point for fine tuning, rather than giving the final settings for Kp, Ti and Td in a single shot. Because of the complex tuning in PID controller, in this work the tuning is done by hit and trial approach. Usually the PID controller is a fixed parametric controller and the power system is dynamic and its configuration changes as its expansion takes place. Hence, fixed parametric PI or PID controllers are unable to give their best responses. To cope up with this complex, dynamic and fuzzy situations and fuzzy logic was proposed in literature by many researchers.

V. FREQUENCY CONTROL OF SINGLE AREA SYSTEM USING AGC

Whenever there is an increase in load on generating unit more amount of real power is to be supplied, which is immediately received from the kinetic energy (K.E) power in rotating part there by reducing K.E of angular velocity

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or speed of the machine. There will be a change in speed which is measure of real power in balance. The change in speed sensed by a speed governing mechanism and control the position of inlet valve to the prime mover, there by controlling the stem water supplied to turbine and hence frequency. This action is a slow process since mechanical elements are involved and usually it takes more time.

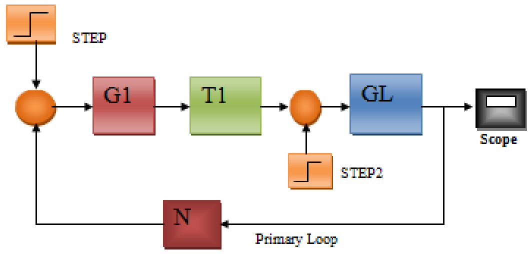

Fig.4 Simulation diagram of single area frequency control by using speed governing system.

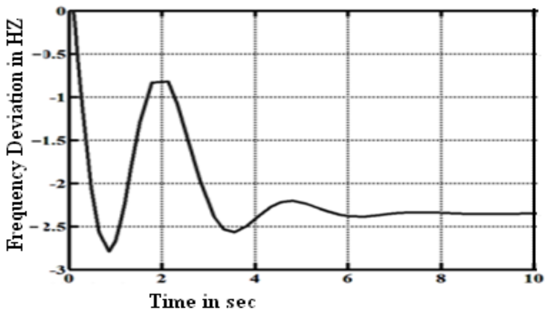

Fig.5 Frequency Response of Single Area for governing system.

VI. SINGLE AREA LOAD FREQUENCY CONTROL WITH USING PID AND FUZZY LOGIC CONTROLLER

Fuzzy logic controller is advanced controller to reduce the frequency error. For reducing of frequency error purpose the in frequency is split into 5 or 7 parts. For each part one membership function (triangular) is assigned. The simulation diagram is shown in Fig.6

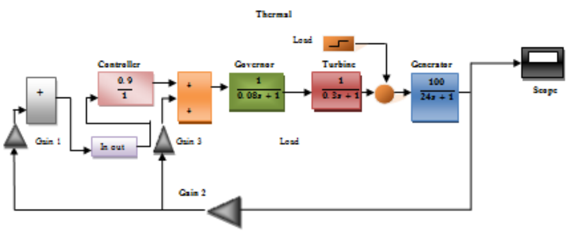

Fig.6 Simulation diagram of single Area load frequency control using PID and fuzzy logic control

FLC= Fuzzy Logic Control , k $=>\frac{1}{2.4}$,G1= Governor $=>\frac{1}{0.08S+1}$, T1=Turbine $=>\frac{1}{0.3S+1}$, GL= Generator load $=>\frac{120}{20S+1}$

The settling time is reduced to 4 sec. And peak overshoot, peak undershoots are also considerably reduced. The frequency error, steady state responses is shown in Fig.7

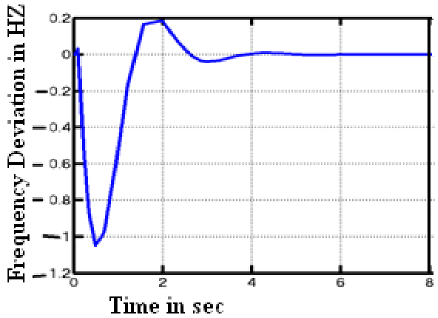

Fig.7 load frequency contro response of single area system with PID and fuzzy logic controller

By using of fuzzy logic controller the dynamic and steady state responses is considerably improved as compared with the conventional controller and PID controller. The performance characteristic values are compared in table 4.

TABLE 4: PERFORMANCE COMPARISON OF SPEED GOVERNOR, PID AND FUZZY CONTROLLERS

Specification / controller	Peak over shoot	Peak under shoot	Settling time
Speed Governor System	---	2.9	8
PID Controller	0.4	2.9	7
Fuzzy logic	0.2	1.01	4

VII. SIMULATION RESULT FOR TWO AREA LOAD FREQUENCY CONTROL (THERMAL TO HYDRO) USING PID AND FUZZY LOGIC CONTROL

In inter connected power system the load frequency control of each area is controlled by different PID controllers. The two areas are interconnected through "Tie line". At balanced condition the Tie line power is equal to zero. Two area interconnected power system the load frequency control using PID and fuzzy logic controller. So generally the characteristics of two areas is same. Means if any disturbance occur the two areas are respond in same manner. So the controller of two thermal areas is very easy. For that two individual fuzzy logic controllers are developed to control the load frequency control from any disturbance. simulation diagram is shown in Fig.8

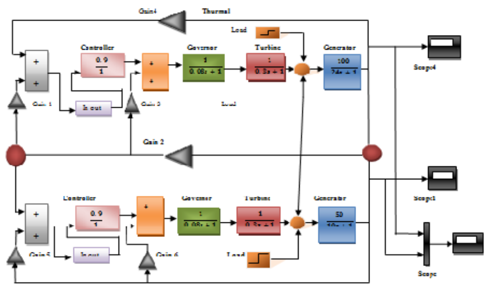

Fig.8 simulation diagram load frequency control by using PID and Fuzzy Controller (Thermal to Hydro)

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By using Fuzzy logic controllers individually in two areas the dynamic and steady state responses are effectively improved. For this in the Fuzzy logic controller the change in frequency error is split into 5 or 7 parts and these parts are in the range from -0.5 to 0.5 is arranged in the membership function. That means the change in frequency may be +ve or –ve. For that the period is taken from –ve to +ve. The simulation diagram of two area (thermal-hydro) system with fuzzy logic controller is shown in Fig.8. Hydro turbines have high moment of inertia than thermal turbines. So generally the change in speed response is very slowly. Due to that the control action is slowly respond in hydro turbines than thermal turbines. The response of two area (thermal-hydro) system with fuzzy logic and PID controller is shown in Fig. 9.

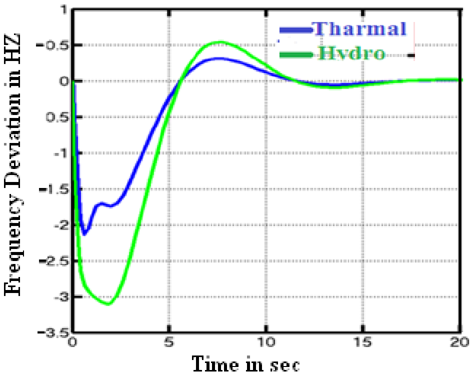

Fig.9 load frequency control response of two area (Hydro - thermul) system using PID and fuzzy logic controller

VIII. CONCLUSION

Fuzzy logic controller gives a very good control action of frequency error, less peak undershoot, less peak overshoot and less settling time as compared with the conventional and PID controllers. The simulation results for single area (thermal), multi area (thermal - thermal and thermal-hydro) power system with conventional P, PI and PID controllers and fuzzy logic controllers is obtained. Hence by using FUZZY logic controller the load frequency control is effectively and quickly reduced. So the power system operation and control is very easy and successfully operated without any damage to the electrical equipment.

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BIOGRAPHIES

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