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Hybrid PID-Fuzzy Controller for AGC in Two Thermal Area

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Abstract: In this study will be highlighted on the construct of an optimal controller in (AGC) circuit for two area system by using many techniques (conventional integral controller KI, Proportional controller PI, Proportional Integral Derivative PID and hybrid fuzzy logic control on adaptive PID-N controller FLC-PID-N to observed and compared the response of the system. When using the above mentioned techniques to achieve better system performance, multi step load disturbance 1-10% will applied to see two area response and to prove that system as (robust system) responds to any change in load. This study will be done using MATLAB Software simulation. The last method mentioned will be done using, planner will be built on rules that enable us to reach the ideal controlling values. This scheme use fuzzy logic to find the controller's values that make PID controller reduces the control error to almost zero. Depending on fuzzy logic, human cogitation is used for controller values optimization, optimal control response can be prospective than that of the PID with constant values.

Key words: System, hybrid fuzzy logic, control, power, units, prospective

INTRODUCTION

Recently, the need for power generation has increased. This growth in demand for three main reasons is the population growth, the great economic activity that is taking place in the current years in addition to increasing the requirements of the individual electric power to provide additional services and electrical appliances in homes, offices and factories, all this led to an increase in demand for energy and that the increase in demand somewhere must be faced well controlled so as not to affect the rest of the electrical grid (Zhao *et al*., 1993; Pati *et al*., 2015).

In power system, (AGC) is used for set the output power of multi units at several electrical plants, to respond to the change in load. Since, a power net demand that generation and demand be almost equal at all time, there should be continuous modifications in the generation as needed, this balance in demand and generation should be observed by observing the frequency value of the system. When the frequency increases that means there is an increase in the generation about the required load and when there is a drop in frequency, means an increase in the load about the amount of generation of power system.

Previously, before entering into details of (AGC), one generating unit in the network will be designed as a control unit to regulate the balance between the generation and the amount of load required to prevent any frequency deviation. Other units will also, be controlled to share a proportion of the load in accordance with the capabilities of that unit. With this systems, several unites in the power system can share load on a single unit to ensure system operation remains within the quality and efficiency standards.

As we know that the electrical network has an interconnection between them facilitates the process of control between areas (AGC) helps to keep the power flowing in these tie lines within its designed limits. With the trend towards computer-based control systems, the control system can take into account several things, including the most economical units, coordination of the types of generating units and even the restrictions related to system stability and network connectivity (Herschel and James, 1994).

Yet, there are many technique and studies used to control and adjust the frequency and maintain error steady state of frequency closely to zero with good transient behaviour and this the main purpose of (AGC) (Ozkop *et al*., 2010).

In literature control technique, there are several researches in the past era for (AGC) of multi area in that region based on several technique such as Traditional, optimized control and intelligent systems represented by (genetic, particle swarm optimization, neural network and fuzzy logic have been used for automatic generation control. Patel and Jain (2013) obviously used artificial neural network to control the error signal and avoid such unwanted behaviour. Also, researchers Gaddam has used Fuzzy Logic Controller and prove that (FLC) best controller than the conventional integral controller (Mallesham and Rajani, 2006). Siraparapu Satyanarayana

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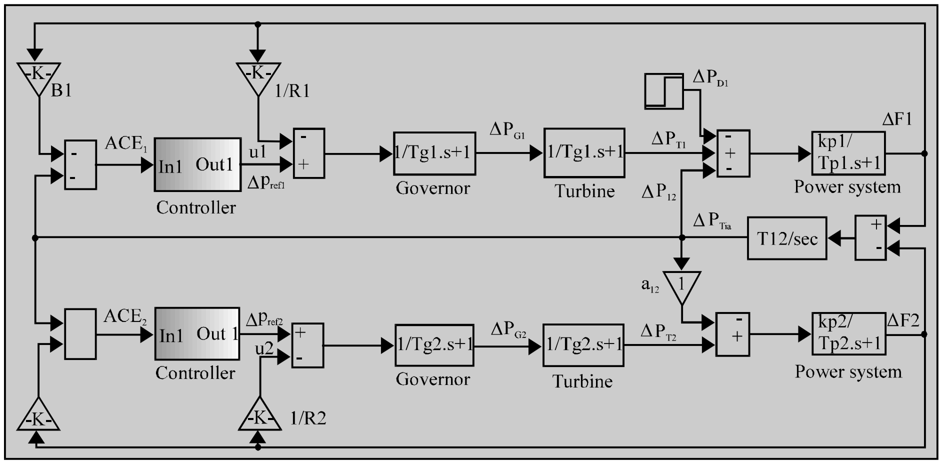

Fig. 1: Two area themal power system

used PID and fuzzy PID by using AGC with Traditional PID controller the number of oscillation, value of over shot and when using fuzzy on PID the improvement achieve on overshoot and settling time (Satyanarayana *et al*., 2014). By Sahu *et al*. (2014) a novel hybrid PSO-PS optimized fuzzy PI controller for AGC in multi area. By Sahu *et al*. (2015) fuzzy on proportional-integral derivative is optimised by DEPSO to reach pragmatic response. By Pan and Liaw (1989) have Provide adaptive control to keep the system in perfect stability.

System construction: A thermal power station (two area system) as illustrative in Fig. 1, everyone has rating of 2000 MW. It is very commonly used with research and studies for the automatic generation control of interconnected areas (Sahu *et al*., 2014; Rout *et al*., 2013; Ali and Abd-Elazim, 2011). Equation show the parameters of all system (gains and time constant) used for area (1, 2):

$$B_1 = B_1 = 0.425 \text{ pu } \frac{MW}{Hz}; \text{ R1 } =$$

$$R_2 = 2.4 \frac{Hz}{p} u.; T_{g1} = T_{g2} = 0.080 \text{ sec}$$

$$T_{t1} = T_{t1} = 0.3 \text{ sec}; k_{p1} = k_{p2} = 120 \frac{Hz}{pu}$$

$$T_{p1} = T_{p2} = 20\text{sec}; T_{12} = 0.545 \text{ pu}; a_{12} = -1$$

Where:

B_1, B_2	=	Frequency bias factor
$(ACE_{(1)}), (ACE_{(2)})$	=	Error signal
u_1, u_2	=	Controller signals R_1 and R_2 the speed regulation parameters
$(Tg_{(1)}), (Tg_{(2)})$	=	Governor time constants
$(T_{(t1)}), (T_{(t2)})$	=	Turbine time constant
$(K_{(p1)}), (k_{(p2)})$	=	Gains of power system
T_{p1}, T_{p2}	=	Time constant of power system
T_{12}	=	Synchronizing coefficient
$\Delta F_1, \Delta F_2$	=	Deflection of frequency

About 1 and 10% load will applied on area 1 to find out and search the performance of the system under study, all techniques (conventional KI, PI controller, PID controller, (FLC-PID-N) will be applied to the system under study to reach the best response.

AGC: It is known that if the demand for the electrical grid increases, the speed of the turbine will drop before the governor set the mechanical energy input to compensate for the shortfall.

And whenever the speed become constant, the error reduces and governor signal becomes with set point we wanted to preserve turbine speed at desired level. But in fact this value is not the exact value, there is some deviation. One way to get rid of the deviation and try to restore speed and frequency to normal value add a controller. Because of its ability to restore system to its exact value it is called reset action. Therefore, as the value of the load changes continuously, the generation must be adjusted in order to get back the frequency value to approximately normal operation point (Sultan, 2014).

Construction refer to above called Automatic Generation Control (AGC). The controller increases System order by 1 to enable the system to return the frequency to the desired value (Saadat, 1999).

In many statuses, multi-unit are neatly coupled internally. Also, the generator turbines head for have the same performance. This multi-unit are called coherent area. And for illustrative purposes The AGC of a multi area can be understand by studying the AGC for a two area. The power transfer flow on the tie line is:

$$P_s = \frac{|E1|E2|}{X12} \sin \delta 12$$

$$X12 = X1+Xtie+X2$$
$$\delta 12 = \delta 1-\delta 2$$

and $\Delta P12$ from the nominal value:

$$P12 = \frac{dP12}{d\delta 12_{\delta 120}} \Delta\delta 12$$

$\delta_{120} = \delta_{10}-\delta_{20}$ the synchronizing power:

$$P12 = \frac{dP12}{d\delta 12_{\delta 120}} = \frac{|E1||E2|}{X12}\cos\Delta\delta 120$$

The interconnection power deflection is:

$$\Delta P_{12} = \left(P_s(\Delta\delta)_1 \Delta\delta_2\right)$$

The flow of power through the interconnection lines appears as an increase in load in an region and a decrease in load in the other region.

The area control error have combination of two component, interconnection line power transfer and drop in frequency multiply by bias factor which given as:

$$ACE_i = \sum_{j=1}^{n} \Delta P_{ij} + k_i \Delta w$$

K_i limit the value of mutual influence during applied load in the neighbouring region. The system will reach perfect response when K_i is equal to the bias factor of that area, Therefore, the error control for a two area system are (Saadat, 1999) given by:

$$ACE_1 = \Delta P_{12} + B_1 \Delta w_1$$

Control strategies used: To dominate the frequency and tie-line power transfer, different control techniques are provided in each area on the area control error signal (ACE).

Conventional integral controller KI: The first technique that has been used to control on Area Control Error (ACE) signal is the integral controller and the value of (KI) is guessed by trial and error method.

Proportional integral controller PI: To make the error value close to zero and for the purpose of getting rid of the frequency drop and restore the normal position within the shortest possible, various controller can used. In this research we will use at first PI controller and observe that the PI result better than conventional integral controller (Mishra and Minakhi, 2014).

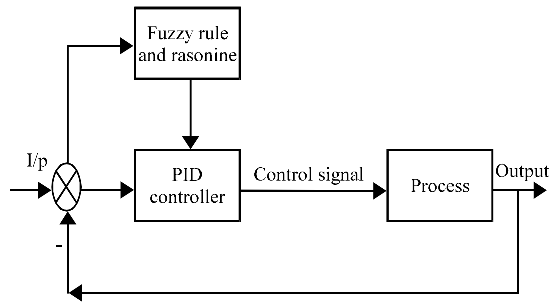

Fig. 2: Fuzzy-PID controller construction

PID controller: The preferable famous controllers used in Various advanced industrial control processes is (PID) controllers because of its good performance and its reflection on adjusting the system response to the right direction which ensures that the error value is reduced to zero (Zhao *et al*., 1993). The PID construction equation is given as:

$$Gc(s) = K_p + \frac{k_i}{s} + k_d s$$

where, k_p, k_i and k_d are the gains of proportional, integral and derivative. With the suitable value of K_p, K_i, K_d which adjusted to reach the best response of system.

Hybrid fuzzy logic controller with adaptive PID-N controller FLC-PID-N

Fuzzy gain scheduling: Because of the power system performance is complex and nonlinear, conventional control technique cannot produce coveted response result. Therefore artificial intelligent controllers can use to get good optimization for controller and optimal performance in frequency deviation troubles (Mathur and Ghosh, 2006). The operation of fuzzy logic is build on rules that follow human thinking on form (If-then) rules. (Mihir, 2006) there are many technique suggested on use the fuzzy logic controller on power system that Differ in the rules and purpose for which they were created (Song and Johns, 1997, 1998).

The values of PID-N parameters, K_p, K_i, K_d or K_p, T_i, T_d can be tamper to give several restraint depending on desired technique and "N" is derivative filter coefficient which lies between [100 150]. Getting optimum modulation of a controller (PID gains and filter coefficient externally) for this desired technique is not measly. In this research, a parameters programming diagram of the PID controllers build on fuzzy logic is introduced (Zhao *et al*., 1993).

From the block diagram observe that, the error signal (e) and the change of error (e^*) Are the inputs of FLC with two output u_1 and u_2 are the control signal of the area as illustrative in Fig. 1-3.

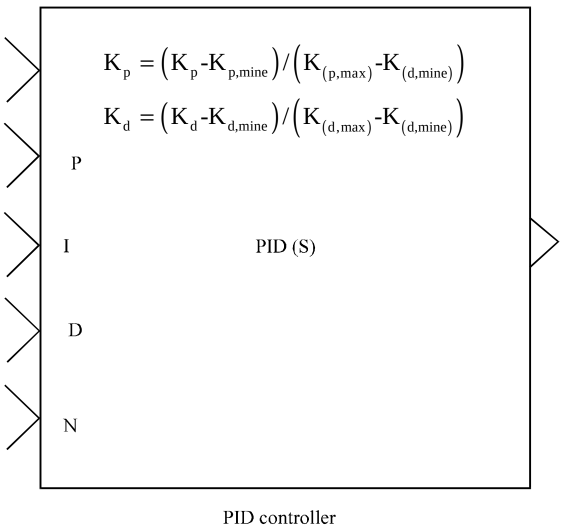

Fig. 3: PID-N structure

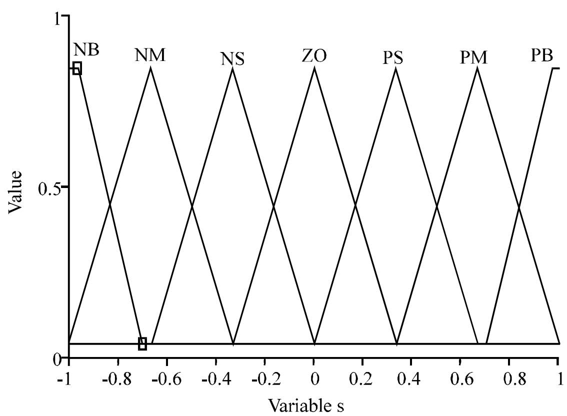

Fig. 4: Membership function of e(k), Δe(k)

Suppose that k_p, k_d in specified limit, for k_p [$k_{p,mine}$, $k_{p,max}$] for. For simplicity, K_d, K_d are normalize with limit between 0 and 1, i.e.

In the fuzzy gain scheduling diagram, PID gains value are find build on the error signal e(k) and change in error Δe(k). The integral parameters value find depending on derivative parameters value, i.e., $T_i = \alpha T_d$:

$$K_i = K_p/(\alpha T_d) = K_p^2/(\alpha K_d)$$

The fuzzy rules are illustrative as shown; if e(k) is A_i and Δe(k) is B_i then K_p is K_p is C_i, K_d is D_i and $\alpha = \alpha_i$, I = 1, 2, ..., m. Here, A_i, B_i, C_i, D_i are fuzzy sets and is α constant (Table 1-3).

The membership diagram for e(k), Δe(k) illustrative in Fig. 4. When NB negative big, NM negative medium, NS negative small, ZO zero, PS positive small and so, on.

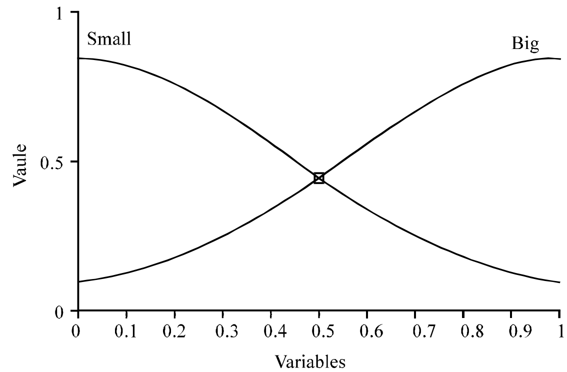

Fig. 5: Membership function of K_p, T_d

Table 1: Fuzzy tuning rules for K_p

	Δe(k)						
e(k)	NB	MN	NS	ZO	PS	PM	PB
NB	B	B	B	B	B	B	B
NM	S	B	B	B	B	B	S
NS	S	S	B	B	B	S	S
ZO	S	S	S	S	B	S	S
PS	S	S	S	B	S	S	S
PM	S	B	B	B	B	B	S
PB	B	B	B	B	B	B	B

Table 2: Fuzzy tuning rules for K_d

	Δe(k)						
e(k)	NB	MN	NS	ZO	PS	PM	PB
NB	S	S	S	S	S	S	S
NM	B	B	S	S	S	B	B
NS	B	B	B	S	B	B	B
ZO	B	B	B	B	B	B	B
PS	B	B	B	S	B	B	B
PM	B	B	S	S	S	B	B
PB	S	S	S	S	S	S	S

Table 3: Fuzzy tuning rules for α

	Δe(k)						
e(k)	NB	MN	NS	ZO	PS	PM	PB
NB	2	2	2	2	2	2	2
NM	3	3	2	2	2	3	3
NS	4	3	3	2	3	3	4
ZO	5	4	3	3	3	4	5
PS	4	3	3	2	3	3	4
PM	3	3	2	2	2	3	3
PB	2	2	2	2	2	2	2

The controller parameter represented by, C_i, D_i may be small or large and this represented by the membership function illustrative in Fig. 5. Therefore, the controller gains are obtained as follows:

$$K_p = (K_{p,max}\text{-}K_{p,mine})K_p + K_{p,mine}$$
$$K_d = (K_{d,max}\text{-}K_{d,mine})K_d + K_{d,mine}$$
$$K_i = K_p^2/(\alpha K_d)$$

Depending on an spacious simulation research on different processes, a rule of thumb for finding the limit of K_p, K_d is given as (Zhao *et al*., 1993):

$$K_{p,\min} = 0.32K_u,\ K_{p,\max} = 0.6T_u$$
$$K_{d,\min} = 0.08K_uT_u,\ K_{d,\max} = 0.15K_uT_u$$

When (k_u is the gain, T_u is the period) of oscillation. It makes the system move towards stabilisty under P-control (Ziegler and Nichols, 1942).

RESULTS AND DISCUSSION

Load disturbance about 1 and 10% utilized in thus, research to understand the dynamic performance of the system. Frequency deviation in two areas will be displayed in results section by using all technique which used in this study to compare the results and conclude the optimal method of control which gives the best performance of the system (Fig. 6-10).

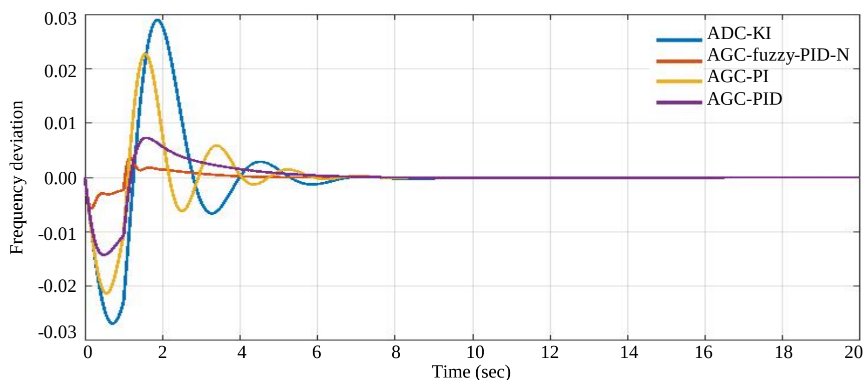

Fig. 6: Frequency deviation of area1 when 1% disturbance applied on area 1

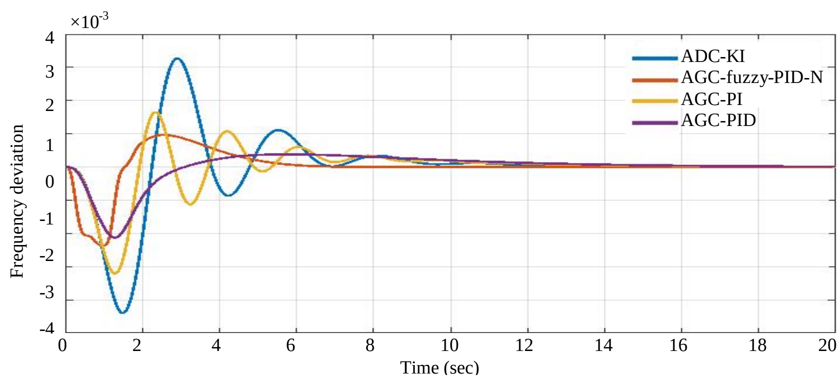

Fig. 7: Frequency deviation of area 2 when disturbance 1% applied on area 1

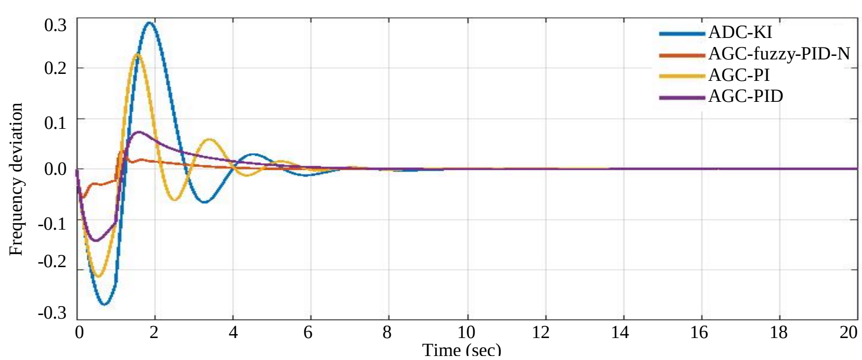

Fig. 8: Frequency deviation of area1 when disturbance 10% applied on area 1

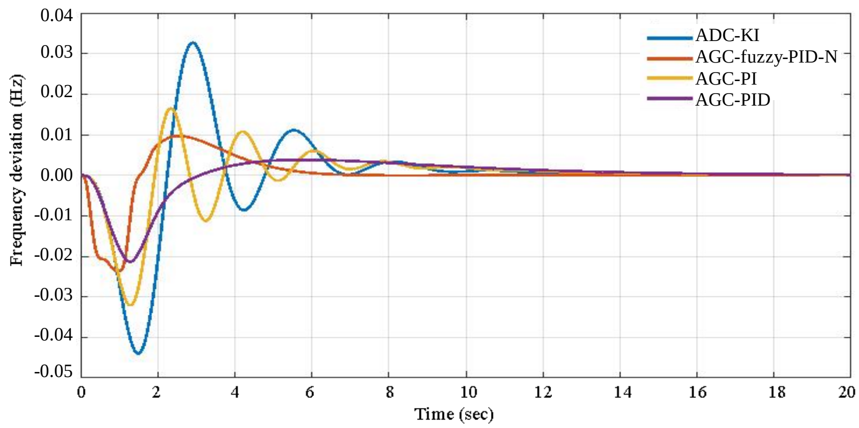

Fig. 9: Frequency deviation of area 2 when disturbance 10% applied on area 1

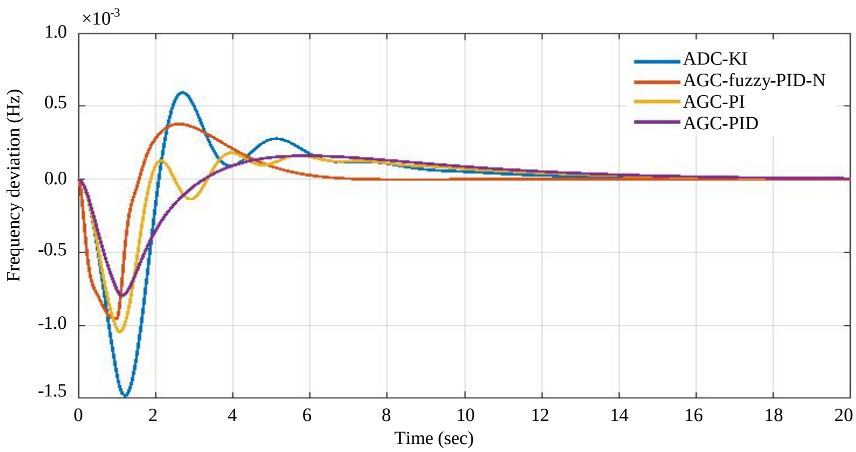

Fig. 10: Change in tie line power transfer

CONCLUSION

Power generation controlling trouble of interconnected power systems has been studied in practice research by dividing the power system into separate regions connected by tie lines to access the best control technology used to reduce the value of error generated when an increase in demand occur and return the system to normal performance, keep power transfer within schedule as little as possible.

The frequency deviation and tie line power transfer introduce a comparison of different controller techniques used on the system under study.

By observing the system performance when using the different techniques, we find that efficient tuning of PID-N controller when use fuzzy logic control on it which gave optimally tune the gain of PID-N and robust system can overcome any change in applied load and restore the system to normal operation conditions represented by frequency deviation, settling time and tie line power transfer.

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