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Automatic Load Frequency Control in Two Area Power Systems using Fuzzy Logic PID Controller

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Abstract—*In this paper Two Areas have been interconnected and system dynamic response has been improved. Also by keeping load demand changes in each area, automatic load frequency control has been seen. Error has been minimized quickly using fuzzy logic PID Controller. MATLAB/SIMULINK software is used in this paper.*

Keywords*: PID, ACE, AGC, ALFC*

1. INTRODUCTION

Small Signal stability is the property of the power system to maintain its synchronism under small disturbances. These disturbances occur continuously on the power system due to small variations in loads and generation [1].

These disturbances give rise to oscillations which must be damped to maintain system stability. Instability can be of two forms: (i) Steady increase in rotor angle due to lack of sufficient synchronizing torque that results in Non-Oscillatory instability. (ii) Rotor oscillations of increasing amplitude due to lack of sufficient damping torque that results in Oscillatory instability [1].

Oscillations can occur in two modes:

(i) Local plant mode Oscillations: These are associated with units at generating station swinging with respect to the rest of the system. The frequencies of these oscillations lie in the range of (0.8- 2) Hz.

(ii) Inter Area Oscillations: These are associated with swinging of many machines in one part of the system against machines in other parts. The frequencies of these oscillations lie in the range of (0.1 – 0.7) Hz [8].

ACE is change in area frequency which when used with tuned PID Controllers helped in bringing system frequency error to zero [2].

AGC helps in maintaining the balance between the generation and demand of a particular power system [7].

In this paper fully automatic control strategy has been used and applied to Two Area interconnected power system. The load demand change in each similar area is kept equal. The frequency change and incremental tie line power has been observed and rectified to improve the system stability and ensuring good and non-interrupted power quality. The necessary system equations have been developed and error being reduced to null point at a quick time. Also with the incorporation of self tuned fuzzy PID Controller, the appearance of Non-linearities and uncertainties in the system is removed or overcome quickly.

2. TWO AREA POWER SYSTEMS

Different controlling units of the power system are connected with the help of Tie lines and the power flowing in these tie lines has to be controlled according to the load demand in either of the connected Areas.

Large Power systems have many interconnected areas in which main aim is to supply reliable power to the consumers even if any load demand change in either of the areas occurs. The continuity of power supply must be maintained at any cost.

The frequency changes are kept uniform by Load Frequency Control (LFC) .Frequency, active powers and rotor angle is being changed while power system is being operated [3].

The following figure illustrates clearly the interconnection among the 2 Areas.

The Two Area Interconnected system block diagram is shown in Fig. 1. The System frequency deviation Δf_i, the deviation in the tie-line power flow $\Delta P_{tie,i}$, load disturbance ΔP_{Di} have been depicted and analyzed.

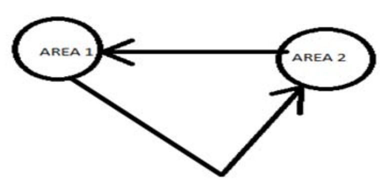


Fig. 1: Interconnected Two Area Power Systems

In this paper, two areas have been interconnected and even a minute change can affect the synchronism of the system, that's why appreciable load demand changes have been applied in both the areas i.e, (2 p.u.). The tuned PID Controllers have been applied in Two Areas to reduce the dynamic disturbances to zero in very quick time. If such disturbances aren't eliminated quickly and exist in the system for greater amount then that may lead to complete shutdown of the system with production of harmonics.

3. ALFC

Automatic Load Frequency Control (ALFC): is being applied in power system to allow an area to first meet its own load demand changes and helps in bringing the steady state frequency of the system Δf to zero.

The frequency and power in case of turbine governor can be related as

$\Delta Pm = (\Delta Pref-1/R*\Delta f)$

Where

ΔPm = change in turbine mechanical power output.

$\Delta Pref$ = change in reference power setting

Δf = change in frequency

R = Regulation constant which identifies the sensitivity of the generator to a change in frequency.

4. FUZZY LOGIC CONTROLLER

Fuzzy controllers have got a lot of advantages compared to the classical controllers such as the simplicity of control, the low cost and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic is one of the successful applications of fuzzy set in which the variables are linguistic rather than the numeric variables. Linguistic variables, defined as variables whose values are sentences in a natural language (such as Large or Small), may be represented by fuzzy sets. Fuzzy set is an extension of a "crisp set" where an element can only belong to a set (full membership) or not belong at all (no membership). Fuzzy sets allow partial membership, which means an element may partially belong to more than one set. A fuzzy logic controller is based on a set of control rules called as the fuzzy rules among the linguistic variables [4].

Structure of self tuned fuzzy logic controller consists of 4 parts:

(a) PID Controller: It is a control loop feedback mechanism widely used in industrial control systems. It generally calculates an error value as the difference between a measured process variable and a desired set point. The performance characteristics of the systems such as rise time, overshoot, settling time , steady state error can be improved by tuning value of parameters (K_P, K_i and K_d) of PID Controller. Mathematically PID is represented as:

$$y(t)=K_p\,[e(t)+T_d\frac{d(e)}{d(t)}+\frac{1}{T_i}\int_0^t e(t)d(t)]\ldots.(vii)$$

$$y(t)=[K_p\,e(t)+K_d\frac{d(e)}{d(t)}+K_i\int_0^t e(t)d(t)]\ldots..(viii)$$

$$K_i=\frac{K_p}{T_i} \text{ and } K_d=K_p.T_d$$

Controller must be sensitive against changes in frequency and load. Intelligent controllers have been used in place of conventional controllers to get fast and better system response in large interconnected power systems [6].

(b) Structure of Fuzzy controller:

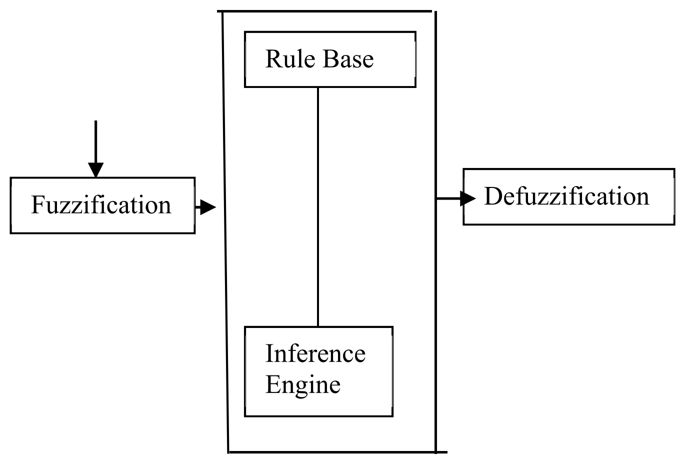


Fig. 2: Structure of Self-tuning fuzzy PID controller:

Here the co-efficients of conventional PID controller are tuned automatically by using fuzzy tuner. [5]

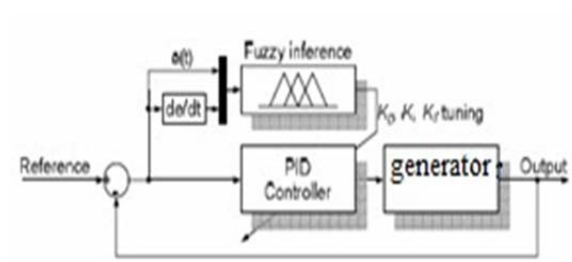


Fig. 2: Structure of fuzzy interface to PID controller.

In the fuzzy logic controller there are four main blocks (i) fuzzification (ii) decision making unit (DMU) (iii) knowledge base (iv) Defuzzification.

The necessary inputs to the DMU block are the rule base and data base units. The fuzzification unit converts the crisp data into the linguistic formats. The DMU decides in the linguistic format with the help of logical linguistic rules supplied by the rule base unit and the relevant data supplied by the data base. Error in voltage e(t) and the change of error voltage de(t) is modeled using the equation: e(t) = E_{ref} - E_G and also de(t) = e(t) – e(t-1) where E_{ref} is the reference voltage and E_G is the generated emf.

The output of the DMU is the input to the defuzzification unit and the linguistic format of the signal is converted back into the numeric format of data in the crisp form. The DMU uses the conditional rules of "IF-THEN-ELSE". In the first stage the crisp variables e(t) and de(t) are converted into fuzzy variables. The fuzzification maps the error and the error changes to linguistic levels of fuzzy sets. The proposed controller uses the following linguistic labels: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero Error (ZE), Positive Small (PS), Positive Medium (PM), Positive Big (PB). Each fuzzy label has an associated membership function. In this paper the membership function of FIS fuzzy editor incorporated with self tuned PID is as shown:

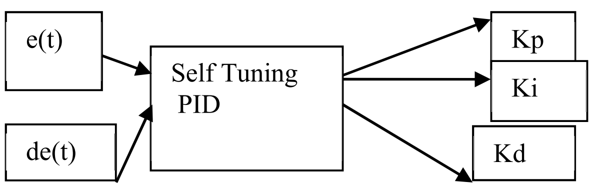


Fig. 3. FIS Fuzzy Inference Block

Rule Base for DMU

E / ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

5. CIRCUIT DESCRIPTION

The following circuit diagram shows the interconnection of Two Area power systems.Gains and time constants of hydraulic amplifier, turbine and power system blocks have been modified and tuned so as to help the PID controllers to reduce rise time, overshoot and the error to zero in 6 secs as evident from the graphs. The output of the PID controller in the areas is given as

$$C= -p*ACE-K_{in}\int ACEdt + K_p \frac{d}{dt}(ACE)$$

When load demand increases, turbine power output also increases in the primary ALFC loop. Rise time and Overshoot gets reduced by Proportional and derivative control whereas the integral control action will reduce the static frequency error to zero. This entire action is performed by secondary ALFC loop. In order to ensure that each network eliminate its frequency deviations is the job of secondary ALFC loop so that finally ΔP_{tie} =0 and Δf = 0. PID controllers here are the network regulators provided in each area having two types of inputs viz., one being the change in frequency and other type being the incremental change in tie-line power which is equal to the difference between the scheduled power and actual power. Thus simulation is performed and keeping the load demand changes in each area, the error has been reduced to zero in 6 seconds with the help of fuzzy tuned PID Controller.

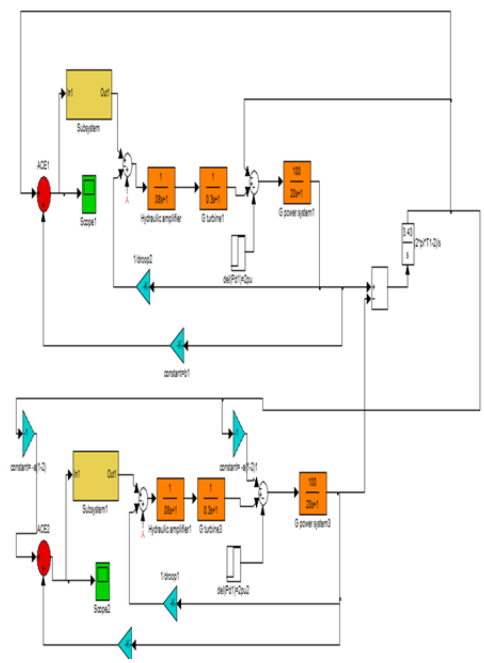


Fig. 4: Two Area Interconnected Power System

6. SYSTEM EQUATIONS

The system equations for both the areas have been developed and shown below:

$$\Delta f(s)=G_P(s)[\Delta P_T(s) - \Delta P_D(s)] \quad (1)$$

$$\Delta f_1 \propto \Delta P_{T1} - \Delta P_{D1} - \Delta P_{12} \quad (2)$$

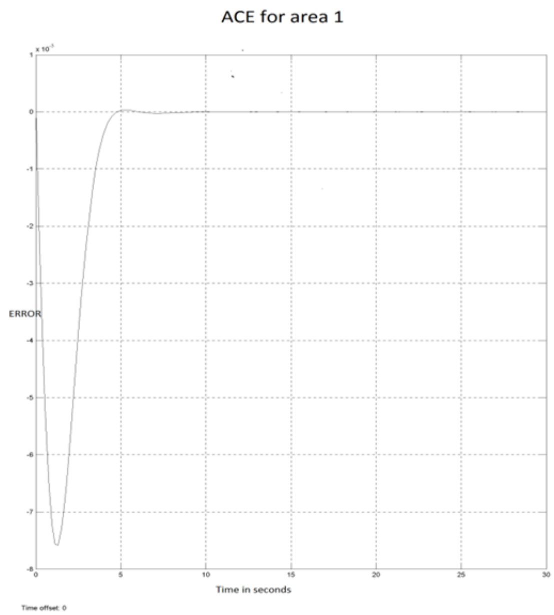
$$\Delta f_2 \propto \Delta P_{T2} - \Delta P_{D2} - \Delta P_{21} \quad (3)$$

$$ACE_1 = \Delta P_{12} + B_1 \Delta f_1 \quad (4)$$

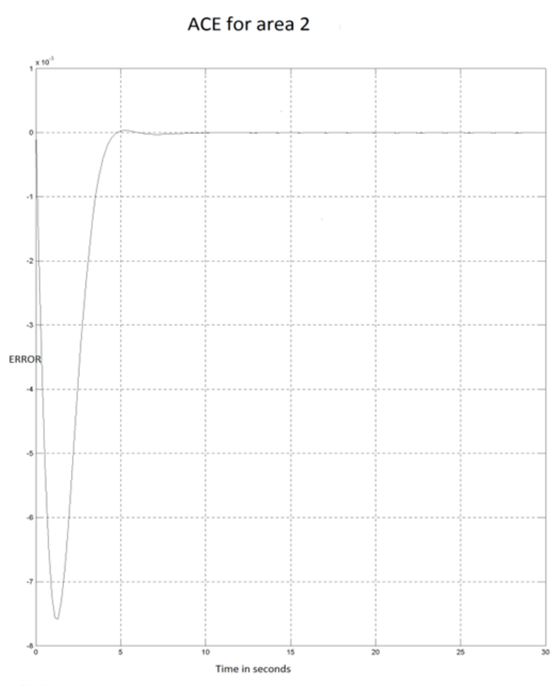
$$ACE_2 = \Delta P_{21} + B_2 \Delta f_2 \quad (5)$$

7. SIMULINK GRAPHS

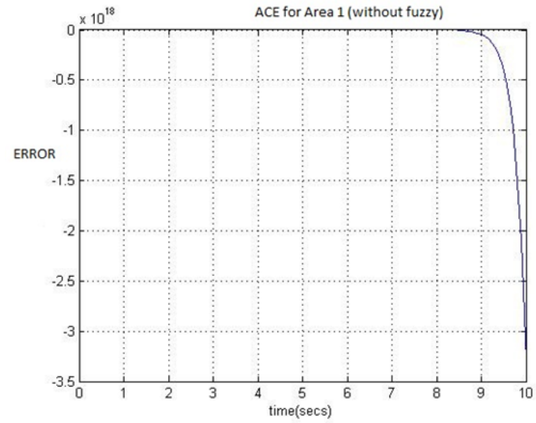
The necessary graphs obtained after simulink the MATLAB Model, are shown in this section.



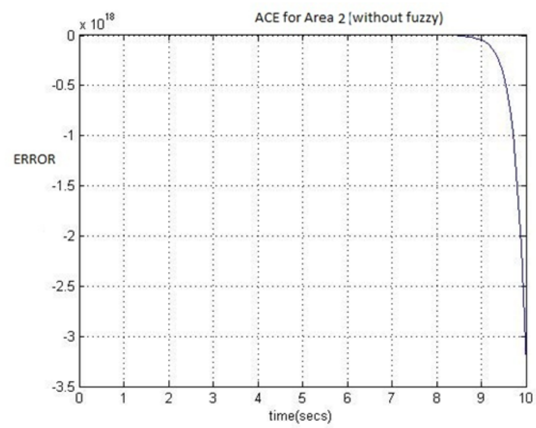
Graph 1: Area Control Error for AREA 1(with fuzzy PID)



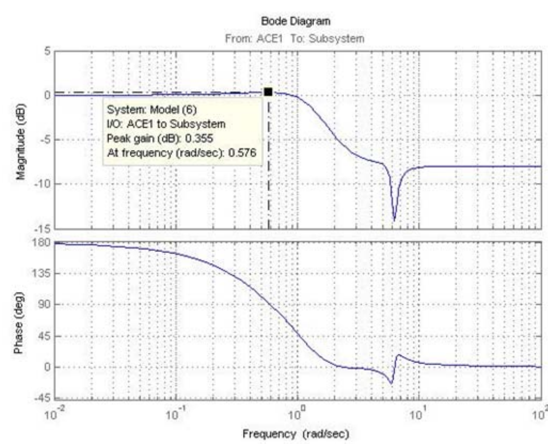
Graph 2: Area Control Error for Area 2(with fuzzy PID)



Graph 3: Area Control Error for Area 1(without fuzzy PID)



Graph 4: Area Control Error for Area 2(without fuzzy PID)



Graph 5: Bode response characteristic showing Peak gain

8. CONCLUSION

In this paper, Area Control Errors in both the Areas have been calculated and change in frequency and tie line power is also being calculated. It is observed that with the application of fuzzy PID Controller, Error in both the areas had been reduced to zero in 6 seconds.Also the continuity of the power is maintained and even if there is a fault in either of the two Areas,it is being compensated by other Area.i.e One area will provide the power to other in case of power shortage or extra load demand.Also Bode Response Characteristic of the two area power system is shown along with the peak gain in graph 5.

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