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Automatic Generation Control of Two-Area System Considering Non-Linearities

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***Abstract*—This paper discuss the Automatic Generation Control (AGC) of Two-Area system considering Non-Linearities and effects of Non-Linearities on Multi-Area system.**

***Index Term*— Automatic Generation Control, Governor Dead Band and Integral Squared Error (ISE).**

NOMENCLATURE

f = Nominal system frequency.
i= Subscript referring to area (i=1, 2, 3). * = Superscript denotes optimum values. P_{ri}=Rated power of i^{th} area.
H_i =Inertia constant of i^{th} area.
ΔP_{tie} = Incremental change in tie line power.
ΔP_{Di} = Incremental load change of i^{th} area.
ΔP_{gi} =Incremental generation change in i^{th} area.
$D_i = \Delta P_{Di}/\Delta f_i$.
T_{ij} = Synchronizing coefficient.
R_i=Governor Speed regulation parameter for i^{th} area.
T_{ri} =Steam turbine reheat time constant for i^{th} area.
T_{ti} = Steam Turbine time constant for i^{th} area.
T_{gi} = Speed governor time constant of i^{th} area.
Tpi=power system time constant of i^{th} area.
$(2H_i/fD_i)$. K_{pi}=Power system gain for i^{th} area $(1/D_i)$.
K_{ri} = Steam turbine reheat coefficient for i^{th} area.
K_{Ii} = gain for integral controller for i^{th} area.
ACE_i=Area control error of i^{th} area.
B_i = Frequency bias for i^{th} area.
K_D, Kp, K_i=Electric Governor Derivative, Proportional and Integral gains, respectively.
$\beta_i = (D_i+1/R_i)$; Area frequency response characteristics for i^{th} area.
J=Cost Index.

I. INTRODUCTION

Normal operation of a multi-area power system requires that each area maintains the generation and load balance. This can be done by means of an automatic generation controller (AGC). AGC maintain the balance by maintaining the system frequency and the tie line flows at their scheduled values during normal condition and also when the system is subjected to small step load perturbations. For normal operating conditions, it is important to minimize unnecessary control action. AGC action is guided by the area control error (ACE), which represents a function of system frequency and tie line flows between two areas. The ACE represents a mismatch between area load and generation taking into account any interchange agreement with the neighboring areas. In this model has been used for AGC studies of a two-area non-reheat thermal system.[1]-[5].

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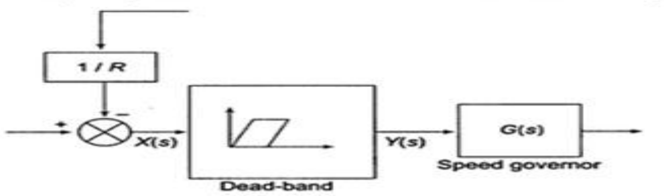
GOVERNOR DEAD-BAND AND ITS EFFECTS

The effect of the speed governor daed band is that for a given position of the governor control valves, an increase/decrease in speed can occur before the position of the valve changes. The governor deadband can materially affect the system response. Mechanical friction and backlash and also valve overlaps in hydraulics relays cause the governor dead-band. Due to this, though the input signal increases, the speed governor may not react immediately until the input reaches a particular value. Similar action takes place when input signal decreases. Thus the governor dead band is defined as the total magnitude of sustained speed change within which there is no change in valve position. The limiting value of dead band is specified as 0.06%.[6][7]



Dead-band in speed-governor control loop

The presence of governor dead-band makes the dynamic response oscillatory. It has been seen that the governor dead-band does not influence the selection of integral controller gain settings in the presence of GRCs. In the presence of GRCs and dead-band even for small load perturbation, the system becomes highly non-linear and hence the optimization problem becomes rather complex.

II. SYSTEM INVESTIGATED

The AGC system investigated consists of two generating areas of equal sizes. Area 1 and area 2 are both thermal systems. Dead-Band of the order of 3% per minute for thermal system

Fig. 1 shows the AGC model of a two area thermal-thermal system with dead-band using integral controller with ISE. A bias setting of $B_i = \beta_i$ is considered in both thermal areas. The system parameters are given in the appendix. The optimum values of derivative, proportional and integral gains for the electric governor have been obtained by using ISE criterion.1% step load perturbation has been considered either in one area or in all areas simultaneously for analysis. The cost function J for the ISE technique is[8][9]

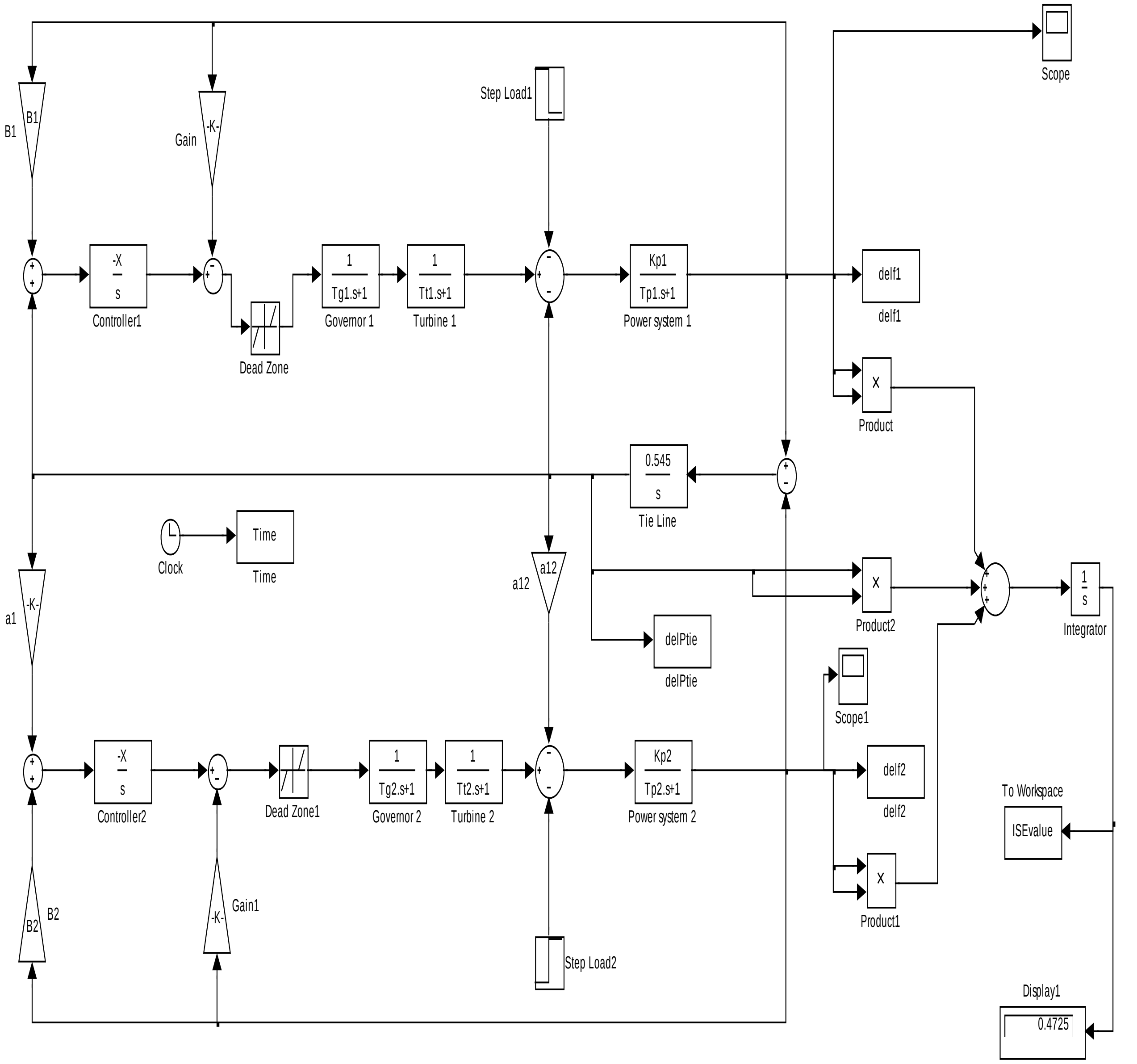
$$J=\int [\Delta P_{t1}^2+\Delta P_{t2}^2+\Delta P_{t3}^2+\Delta f_1^2+\Delta f_2^2+\Delta f_3^2]\, dT$$

Where,

dT=small time interval during sample,

ΔP_{ti} =incremental change in tie power,

Δf_i =incremental change in frequency.

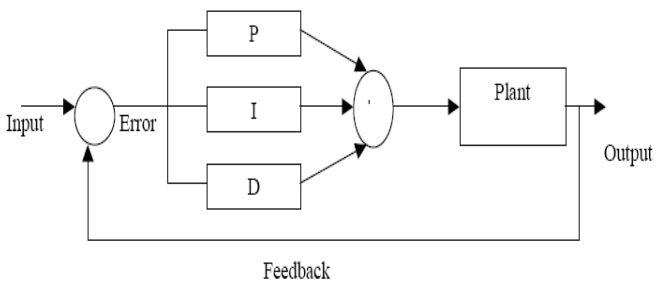


III. CONTROLLER FOR AGC

A. PID CONTROLLER

PID controller consists of Proportional Action, Integral Action and Derivative Action. It is commonly refer to Ziegler-Nichols PID tuning parameters. It is by for the most common control algorithm.

PID controllers can be implemented in many forms. It can be implemented as a stand-alone controller as part of Direct Digital Control (DDC) package or even Distributed Control System (DCS). The latter is a hierarchical distributed process control system which is widely used in process plants such as pharceumatical or oil refining industries.[8]



The three controllers when combined together can be represented by the following transfer function

$Gc(s) = K (1 + 1/sT_i + sT_d)$

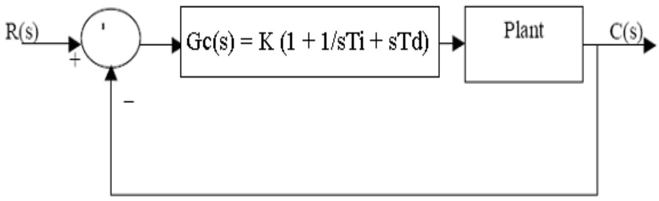


Fig-2 continuous PID controller

B. INTEGRAL CONTROLLER

In integral control,

$I_{term}=K_I * \int Error\ dt$

It is proportional to the amount of error in the system. In this action, the Integral action will introduce a lag in the system.[9]

C. FUZZY CONTROLLER

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multi-valued logic. But in a wider sense, which is in predominant use today, fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL.

Fuzzy Logic Toolbox for use with MATLAB is a tool for solving problems with fuzzy logic. Fuzzy logic controllers formulate the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decision can be made. This method has a distinguishing feature in which it can express linguistically complex non-linear system.

The basic configuration of fuzzy logic controller (FLC) has four parts

- Fuzzification of input
- Knowledge base
- Decision making logic
- Defuzzification of outputs

IV. SIMULATION RESULTS

Simulation is done on MATLAB software. Results are based on simulation of two area system with PID controller, Integral Controller, Fuzzy logic controller implementation.

Simulation results with PID controller on two area system

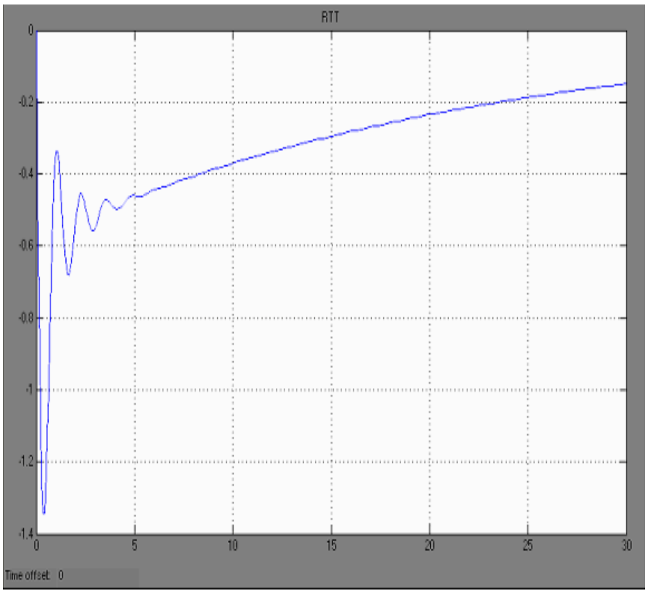


Fig 3 Frequency response of area 1 with PID controller

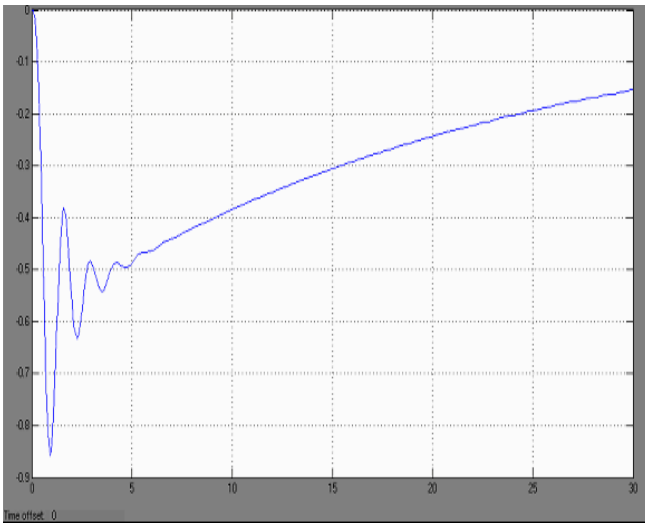


Fig 4 Frequency response of area 2 with PID controller

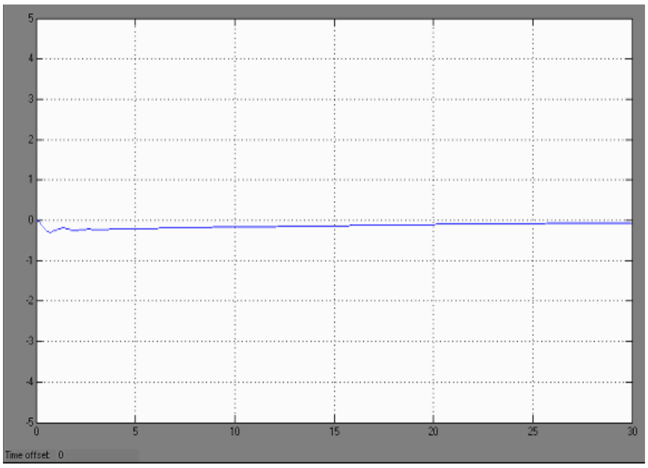


Fig 5 Response of Tie line power with PID controller

V. SIMULATION RESULTS WITH INTEGRAL CONTROLLER

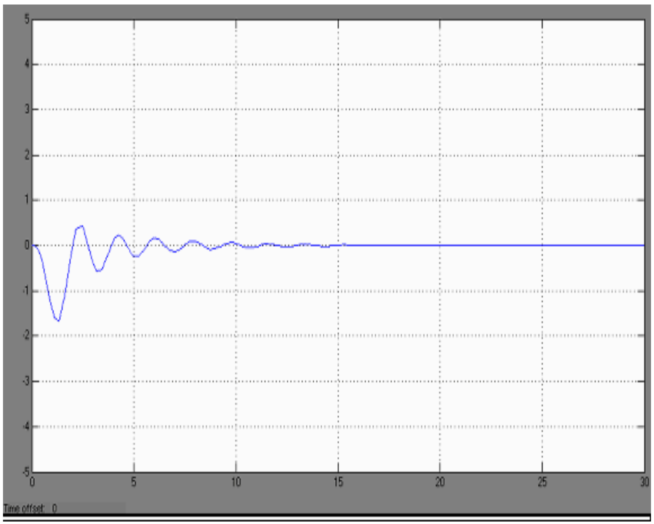


Fig 6 Frequency response of area 1with Integral controller

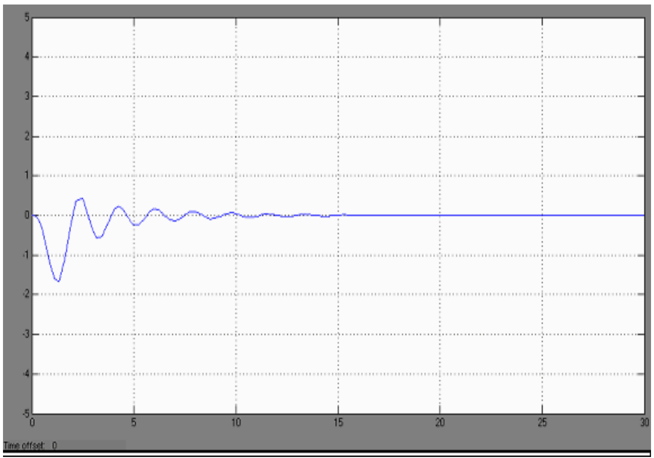


Fig 7 Frequency response of area 2 with Integral controller

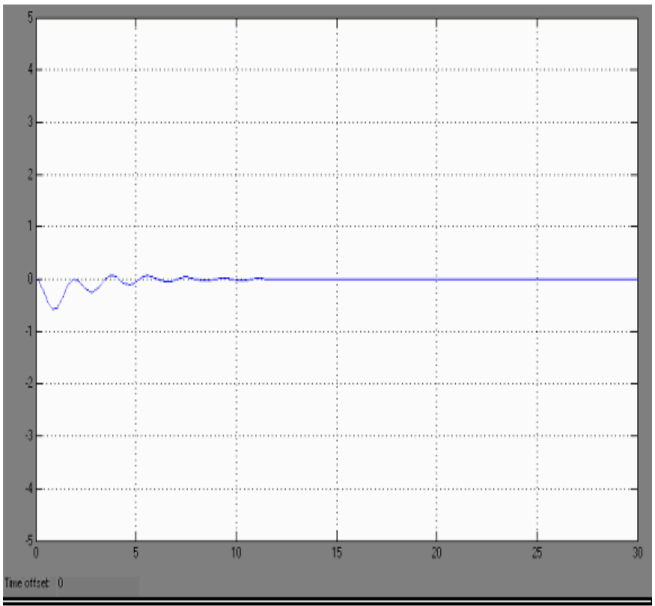


Fig 8 Response of Tie line power with Integral controller

SIMULATION RESULTS WITH FUZZY CONTROLLER

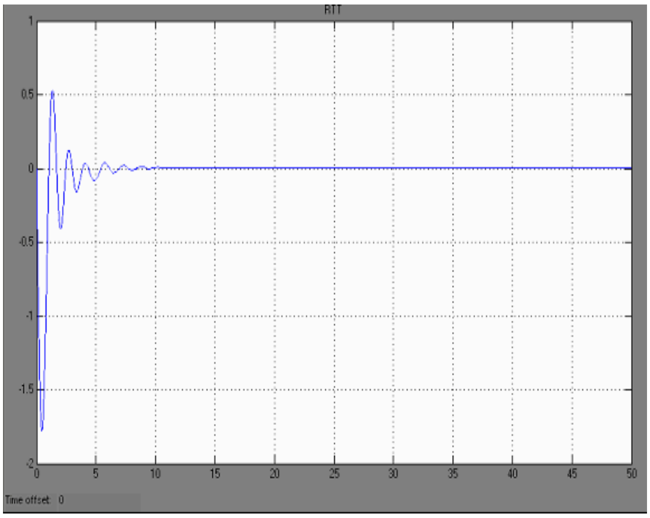


Fig 9 Frequency response of area 1with fuzzy controller

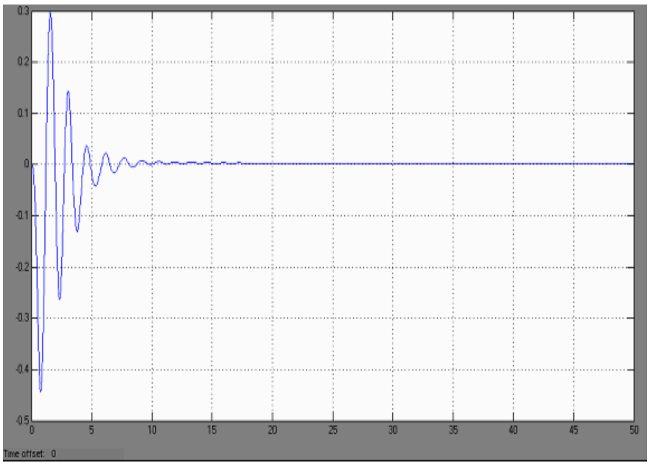


Fig 10 Frequency response of area 2 with fuzzy controller

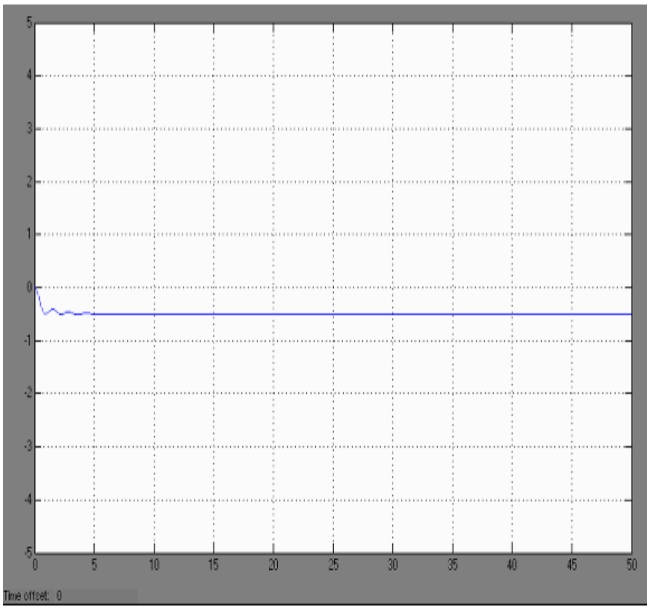


Fig 11 Response of Tie line power with fuzzy controller

VI. COMPARISON

Comparison with Integral and PID controller and Fuzzy

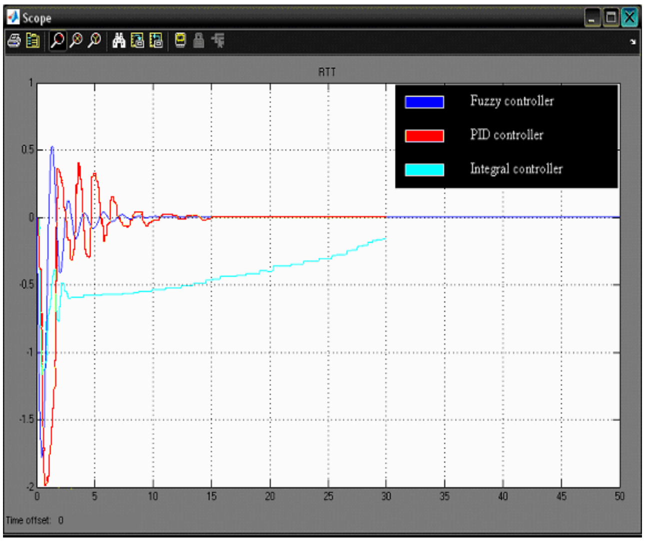


Fig 12 Comparison of frequency response of various controllers

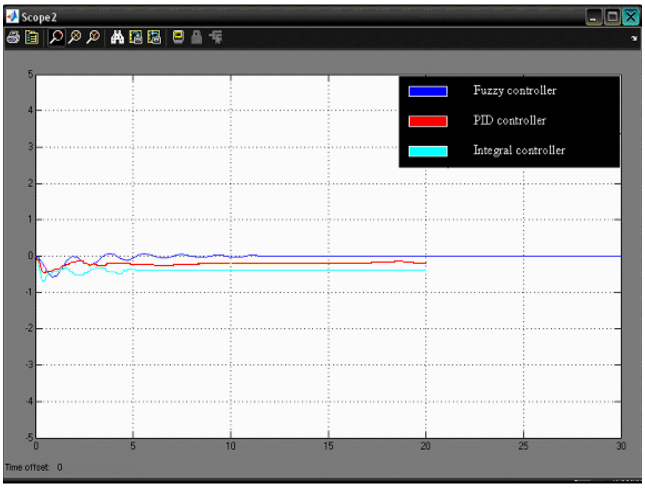


Fig 13 Comparison of Tie Line Power Response of various controllers.

VII. CONCLUSION

In the present work a two area thermal system has been studied with a view to design Integral, PID and Fuzzy controllers and study the dynamic performance of the system. Based on the results reported in the previous chapters, the following conclusions can be made.

1. For unit step perturbation in load the settling time in the frequency response for fuzzy logic controller is 10ms, for PID controller is around 15ms and for integral is more than 30ms. This clearly indicates that FLC proves to be the best controller for the system.
2. In case of Fuzzy controller, the frequency error is zero at 10ms but in case of integral controller the frequency error remains at -0.55Hz and in case of PID controller it is around –0.01Hz.
3. The number of triangular MF has an impact on dynamic responses and hence needs to be properly selected.
4. Presence of FLC in both areas and small step perturbation in both areas simultaneously provides zero steady state error.
5. The peak deviation and the amplitude of oscillations in the tie line increase with the increase in tie strength independent of the area capacity of the system.

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