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Thermal- Hydro Power Systems Control by HFTID Controller

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***Abstract*—** In power system the active and reactive power demands are never steady and they are continually changing with the rising or falling trend of load demand. Steam input to turbo-generators (or water input to hydro-generators) must be regulated continuously to match the active power demand in case of falling or rising trend of load demand failing which results in consequent change in frequency which is highly undesirable (maximum permissible change in frequency is $^{+}_{-}$ 0.5 Hz).We may note that the frequency is affected mainly due to the change in real power while the reactive power is less sensitive due to the change in frequency and depends only on voltage magnitude. Thus, real and reactive power is controlled separately. The load frequency control (LFC) loop which we had taken for our discussion control the real power and frequency only. This Paper presents, the effect of Fuzzy and HFTID controller on the stability of reheat thermal- hydro interconnected power system. In this study hybrid fuzzy-PID controller is used which is usually called in general Hybrid Fuzzy Tilt Integral Derivative Controller this enhance the robustness and performance of the controller. Two performance parameters were used for the comparison. First one being the settling time and other is the overshoot of the frequency deviation were compared.

***Keywords*—** Area control error, fuzzy control, HFTID control, load frequency control, tie line power control.

I. Introduction

Power system operation which we had considered so far was under conditions of steady load. But however in actual, both active and reactive power demands are never steady and they are continually changing with the rising or falling trend of load demand. Changes in real power affect mainly the system frequency, while reactive power is less sensitive to changes in frequency and is mainly dependent on changes in voltage magnitude. Thus, real and reactive powers are controlled separately. The load frequency control (LFC) loop controls the real power and frequency and the automatic voltage regulator (AVR) loop regulates the reactive power and voltage magnitude. The Load frequency control (LFC) has gained in importance with the growth of interconnected systems and has made the operation of interconnected system possible which is broadly discussed in Section-III. The main objective of the LFC is to maintain reasonably uniform frequency, to divide the load between generators, and to control the tie-line interchange schedules. Frequency is one of the stability criteria for large-scale stability of power networks. For stable operation, constant frequency and active power balance must be provided. Any change in active power demand / generation at power system is reflected throughout the system by a change in frequency. In interconnected power networks, frequency variation can lead to serious stability problems. To improve the stability of the power system it is necessary to design a load frequency control (LFC) systems that controls the power generation and active power at tie-lines. So for automatic generation control we need different controllers which stabilize the system response due to disturbances in a short period of time. Different techniques of stabilization have been discussed in Section-II.

II. Techniques of Stabilization

Different controllers had been used now days for automatic generation control and voltage regulation for generator. Some of them are as follows:-

1. PI Controller: - Conventional Proportional plus Integral controller (PI) makes the system response to be steady state in the farm of frequency deviation, but it exhibits poor dynamic performance (such as no. of oscillation and more settling time).

$$u(t) = Kpe(t) + Ki\int_0^t e(\tau)d\tau$$

2. PID Controller: - A Proportional – Integral – Derivative (PID Controller) is a control closed loop feedback mechanism system as shown in Fig. 1 and it is widely used in industrial control System. It exhibits good dynamic performance (such as no. of oscillations and setting time) and is better as compared to PI Controller.

$$u(t) = Kpe(t) + Ki\int_0^t e(\tau)d\tau + Kd\frac{de}{dt}$$

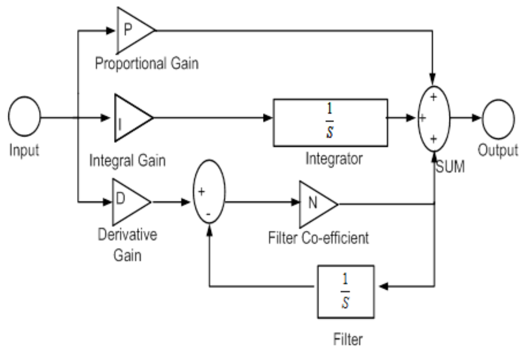

Fig. 1. Simulation model of PID controller.

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3. Fuzzy Logic Controller: - In the present scenario Fuzzy Logic Control system applications become very useful. The Fuzzy logic controller as shown in Fig. 2 is framed by the combination of different interfaces named as fuzzification interface, the inference rules design interface and defuzzification interface. It exhibits very good dynamic performance and is better as compared to PI and PID controller.

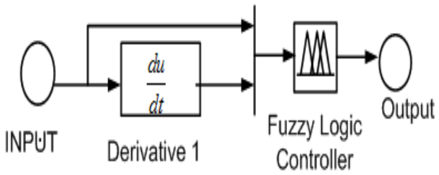

Fig. 2. Simulation model of FLC.

4. HFTID Controller: - A Hybrid Fuzzy-TID (Tilt-Integral-Derivative) Controller is a new approach to get the better result as compare to the PI, PID and Fuzzy Controller.

In a PID Type Compensator, where the proportional compensating unit is replaced by a compensator designed to have a transfer function denoted by 1/S (1/n). This is called 'Tilt' Compensator. So the entire compensator act as a Tilt-Integral-Derivative (TID) Compensator as shown in Fig. 3. It exhibits very good dynamic performance as compared to PI, PID and Fuzzy Controllers as shown in Fig. 4.

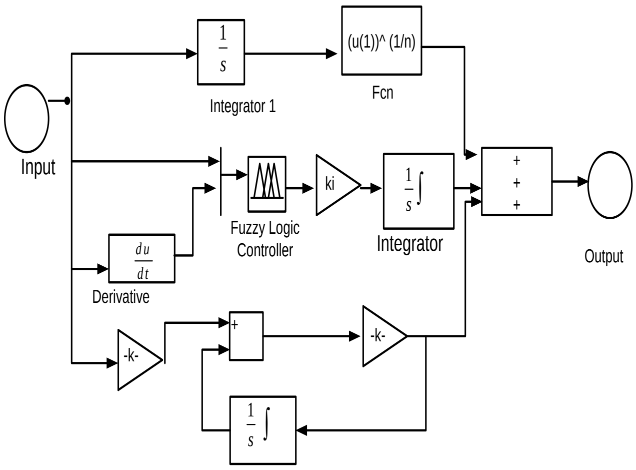

Fig. 3. Simulation model of HFTID controller.

III. THEORY OF AGC

To increase the reliable and uninterrupted power supply, there is a necessity to maintain the certain parameters of the power systems. In this study the main attention is given to the frequency deviations, peak overshoots and settling time of a reheat thermal-hydro interconnected power systems. Normally, thermal system consumes base load and hydro system for peak load, due to easiness in control. The fluctuation of load in these systems is very common, which can either reduce their efficiency or may indulge the system to behave in an abnormal manner or may damage it, but these issues can be prevented by the use of different controllers in order to make the system response to different controllers in order to make the system response to be steady state. The controllers which are commonly used now days are conventional PI and fuzzy logic controller

Automatic generation control (AGC) is defined as the controlling of the regulation of controllable generators within a certain controllable limits with reference to the change in system frequency so as to maintain the steady state system frequency. To maintain the system frequency to be steady state AGC plays an very important role and also scheduled the system parameters values during normal period. The synchronization of different system to interconnected system depends upon (1) voltage magnitude (2) frequency and (3) phase sequence. It is to be noted that the wide variations of the system parameters like frequency voltage will lead the system to become uncontrollable or totally collapsed.

As frequency deviations generally take place due to the change in load at demand side as a result there is also a corresponding change in tie line power signal also which are then combined and feed to the controllers in the farm of a control signal. The combined signal which is feed to the controller is known as area control error (ACE). ACE is generally used to indicate when total generation must be lowered or raised in a particular control area which can be controllers. Maintaining the system frequency at steady state is very important for the generating equipments as well as for the equipments to be used at the consumer end. Hence we can say that due to the rising energy needs of any nation AGC become very useful for the interconnection of different systems to meet the increased energy needs as well as to maintain the system response to be steady state with the change in load.

In a dependent power system, the main issue is to maintain the interchange power transfer. Therefore the function of AGC is to restore frequency to the specified nominal value. With the primary LFC loop as shown in Fig. 5. the system frequency deviations due to changes in load were maintained to be steady state, which mainly depends on the regulation of governor speed . In order to reduce the frequency deviation to zero, we must need an reset action that can be achieved with the help of integral controller which changes the speed rotation settings of the turbine with reference to load perturbations. The integral controller increases the system by type 1 which forces the final frequency deviation to zero and their methodology is discussed in Section-IV. The LFC loop of a interconnected areas are shown below in Fig. 5.

IV. METHODOLOGY

For analyzing the system performance, the mathematical model is required. Moreover, the control system can be designed only if the complete mathematical model of the system exists. The mathematical model of reheat thermal and hydro power plants has been considered in this paper.

From the block diagram of reheat thermal-hydro interconnected power system consists of transfer functions of speed governor, Generator and steam turbine , similarly hydro power system consists of transfer functions of electric generator, Hydro turbine and Generator system as shown in Fig. 5.

While performing Simulations on reheat thermal–hydro interconnected system by using HFTID and Fuzzy controller

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the parameters to be used in Fig. 7 and Fig. 8 are as follows while their results and comparison are separately discussed in Section V.

Nominal system frequency (F) =60Hz, Governor speed regulation parameters (R_i) =2.4 Hz/per unit MW, Steam governor time constant (T_g) =0.08sec, Reheat time constant (T_r) =10.0sec, Reheat constant (K_r) =0.5sec, Inertia Constant (H_i)=5sec, Area rated power(Pri) =2000MW, Steam turbine time constant (T_t) =0.3sec, D_i =$8.33*10^{-3}$ p.u. MW/Hz, Water starting time(T_w)=1.0 sec, T_{Pi}= 20sec, K_{pi} = 120Hz.p.u./MW where T_{pi}= $2H_i/\ f^* D_i$, Di = $\Delta P_{Di}/\Delta f_i$, K_{pi} = $1/D_i$, Integral Controller (K1=K2) = 0.2/S, ACE= Area Control Error, B_i=Frequency bias factor, K_P =1.0, K_i =5.0, K_d =4.0, K_d, K_p, K_i = Electric governor derivative, proportional and integral gains, respectively, i = Subscript referred to area.

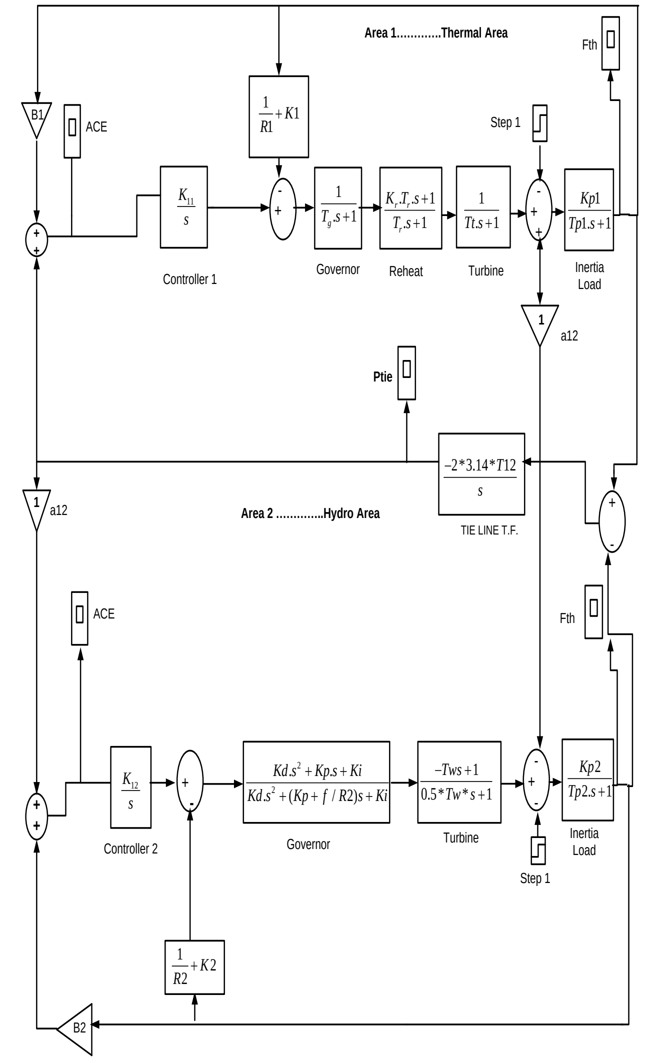

Fig. 5: Composite block diagram of two area load frequency control.

The fuzzy logic controller block is designed by the combination of area control error ACEi and by the rate of change of area control error Δ ACE_i. It mainly consists of three interfaces blocks which mainly consist of two-inputs and one output. Each membership function consists of two trapezoidal membership and five triangular memberships as shown in Fig. 6. The mechanism is realized by 49(7×7) rules for the fuzzy controller block. The following membership functions used for the designing the fuzzy controllers are shown in table I.

TABLE I. Fuzzy logic rules for HFTID controller.

ACE/ΔACE	LN	MN	SN	Z	SP	MP	LP
LN	LP	LP	LP	MP	MP	SP	Z
MN	LP	MP	MP	MP	SP	Z	SN
SN	LP	MP	SP	SP	Z	SN	MN
Z	MP	MP	SP	Z	SN	MN	MN
SP	MP	SP	Z	SN	SN	MN	LN
MP	SP	Z	SN	MN	MN	MN	LN
LP	Z	SN	MN	MN	LN	LN	LN

*LN: Large Negative; MN: Medium Negative; SN: Small Negative; Z: Zero; SP: Small Positive; MP: Medium Positive; LP: Large Positive

In the simulink model in Fig. 7 the controller block of block diagram in Fig. 5 is replaced by a HFTID Controller and rest of the blocks with their respective values as shown below in Fig. 7. Similarly in the simulink model in Fig. 8 the controller block of block diagram in Fig 5 is replaced by a Fuzzy Controller and rest of the blocks with their respective values as shown below in Fig. 8

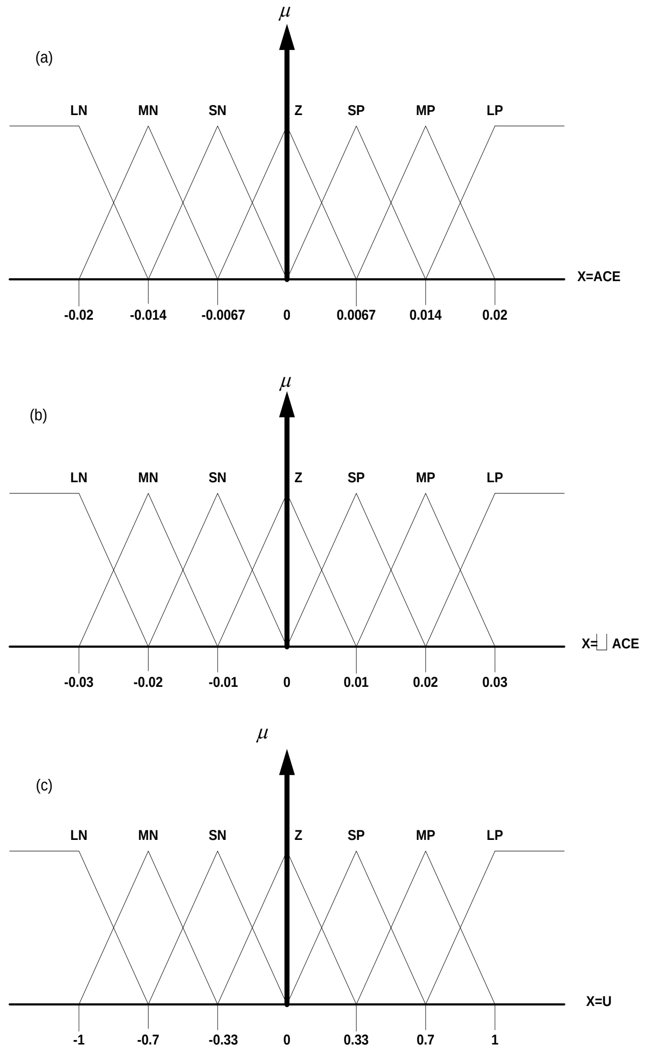

Fig. 6. Membership functions of (a) ACE (b) ACE (c) U for the FLC controller.

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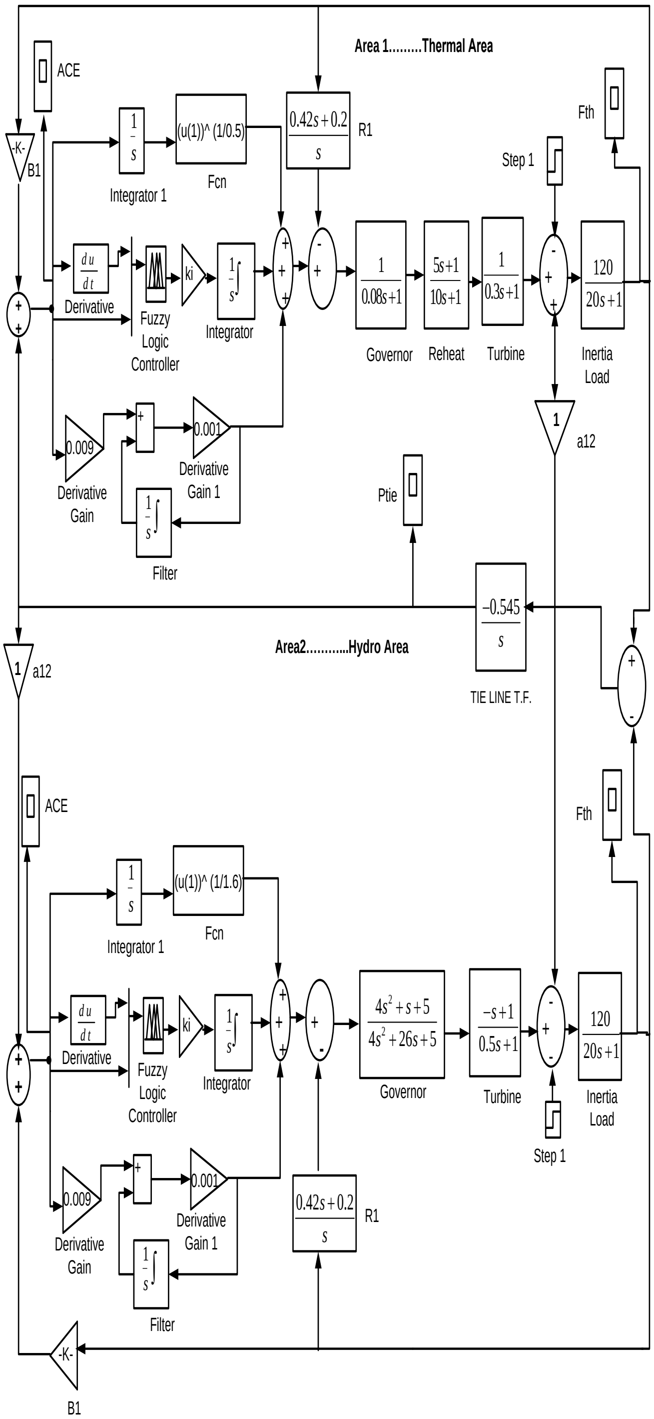

Fig. 7. Simulation Model with HFTID Controller.

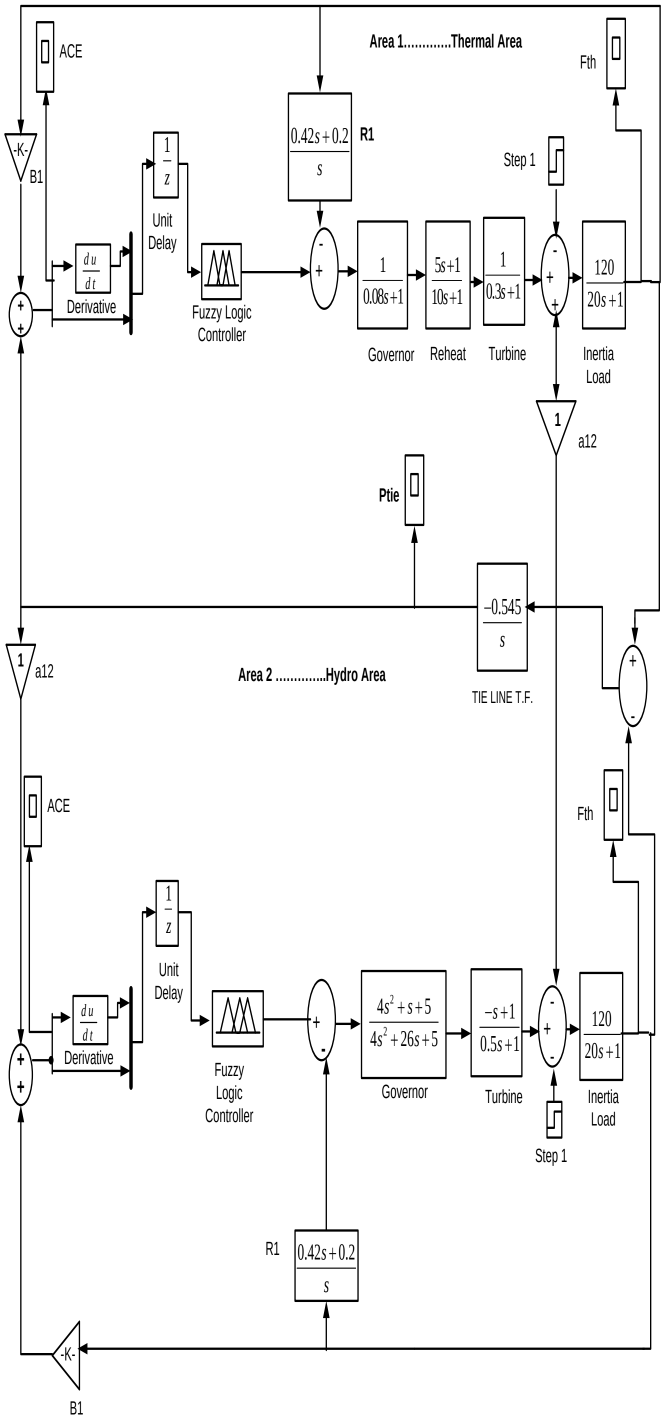

Fig. 8. Simulation model with Fuzzy Controller.

V. Results Discussions and Tables

Comparison of system performances with Fuzzy and HFTID Controller on two area reheat thermal- hydro interconnected power system at .2 Step Change in Load. Simulation studies are performed to investigate the performance of the two area Reheat thermal-hydro interconnected power system. A step load disturbance of .2 of the nominal loading is considered in both the areas.

Fig. 9 and Fig. 10 depicts the dynamic responses of the reheat thermal system in the farm of frequency deviations and area control error with .2 step change in load by using fuzzy controller. Fig. 11 and Fig. 12 depicts the dynamic responses of the hydro system in the farm of frequency deviations and area control error with .2 step change in load by using Fuzzy controller. Fig. 13 depicts the dynamic responses of the reheat thermal-hydro interconnected system in the farm of change in tie line power with .2 step change in load by using Fuzzy

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controller. Fig. 14 and Fig. 15 depicts the dynamic responses of the reheat thermal system in the farm of frequency deviations and area control error with .2 step change in load by using HFTID controller. Fig. 16 and Fig. 17 depicts the dynamic responses of the hydro system in the farm of frequency deviations and area control error with .2 step change in load by using HFTID controller. Fig. 18 depicts the dynamic responses of the reheat thermal-hydro interconnected system in the farm of change in tie line power with .2 step change in load by using HFTID controller. Fig. 19 and Fig. 20 shows the comparison of dynamic responses of the thermal system in the shape of frequency deviations and area control error with .2 step change in load by using fuzzy and HFTID controller. Fig. 21 and Fig. 22 shows the comparison of dynamic responses of the hydro system in the farm of frequency deviations and area control error with .2 step change in load by using fuzzy and HFTID controller. Fig. 23 shows the comparison of dynamic responses of the reheat thermal-hydro interconnected system in the farm of change in tie line power with .2 step change in load by using fuzzy and HFTID controller.

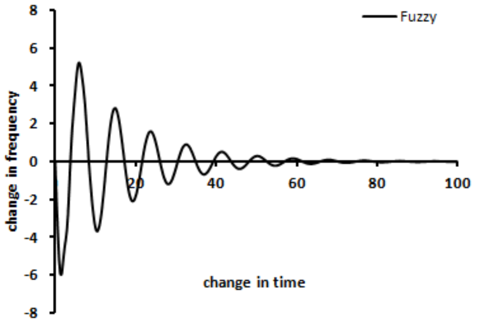

Fig. 9. Frequency response of reheat thermal system by using fuzzy controller.

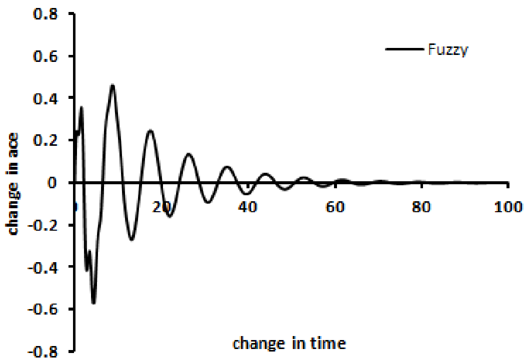

Fig. 10. ACE response of reheat thermal system by using fuzzy controller.

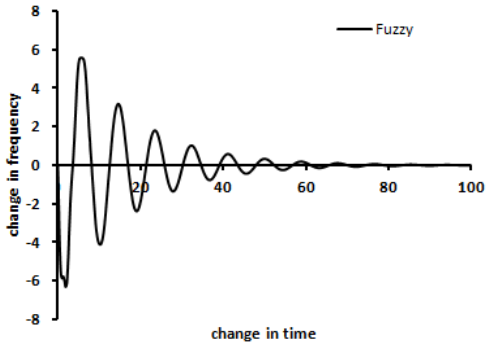

Fig. 11. Frequency response of hydro system by using fuzzy controller.

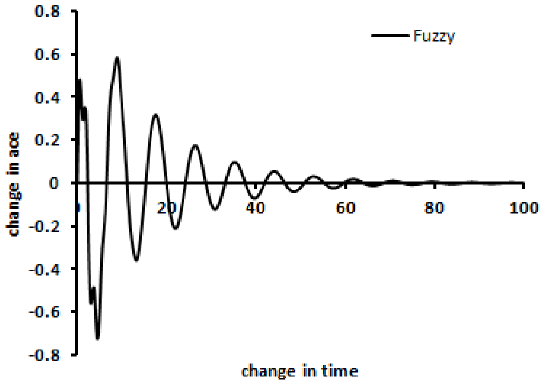

Fig. 12. ACE response of hydro system by using fuzzy controller.

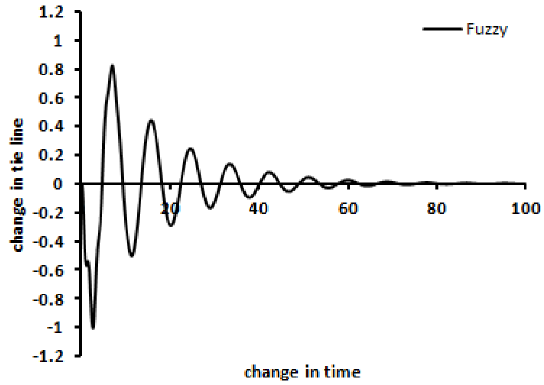

Fig. 13.Tie line response of reheat thermal - hydro interconnected system by using fuzzy controller.

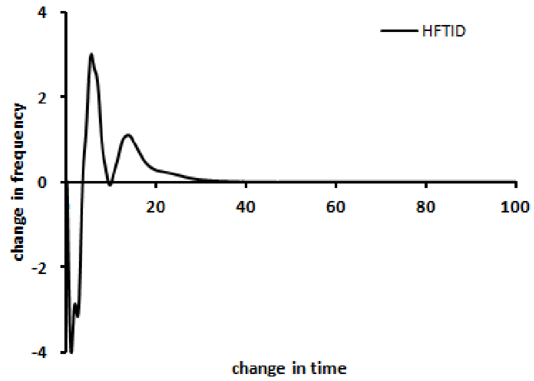

Fig. 14. Frequency response of reheat thermal system by using HFTID controller.

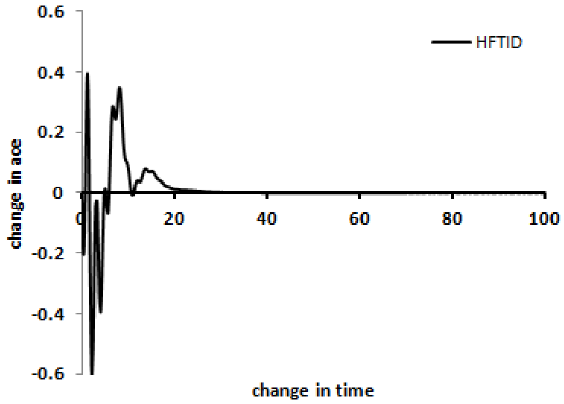

Fig. 15. ACE response of reheat thermal system by using HFTID controller.

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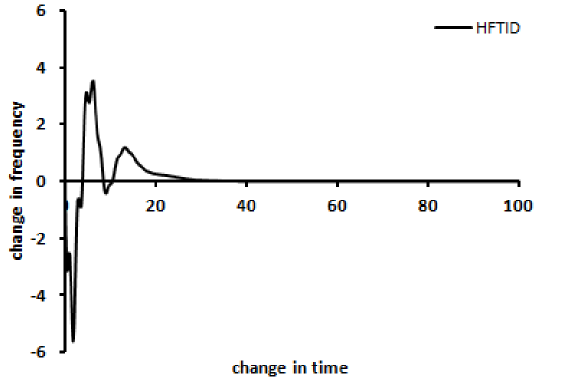

Fig. 16. Frequency response of hydro system by using HFTID controller.

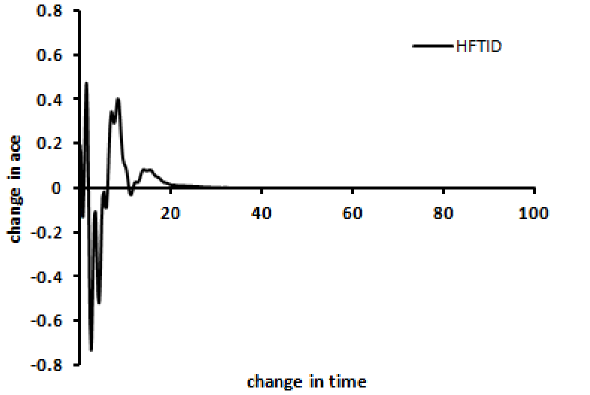

Fig. 17. ACE response of hydro system by using HFTID controller.

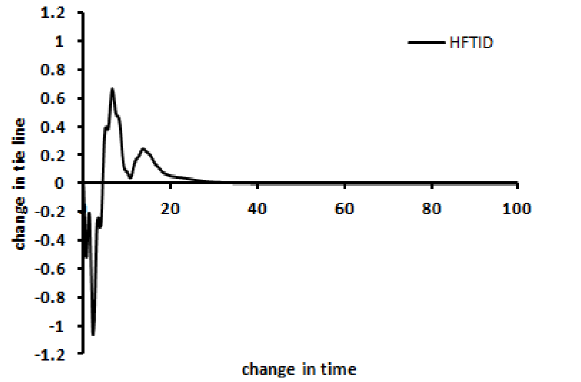

Fig. 18. Tie line response of reheat thermal - hydro interconnected system by using HFTID controller.

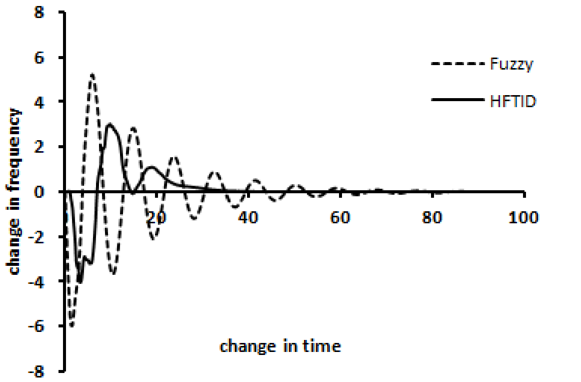

Fig. 19. Comparison of frequency response of reheat thermal system by using fuzzy and HFTID controller.

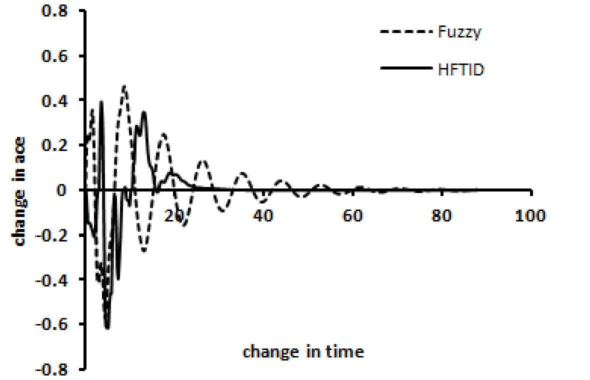

Fig. 20.Comparison of ACE response of reheat thermal system by using Fuzzy and HFTID controller.

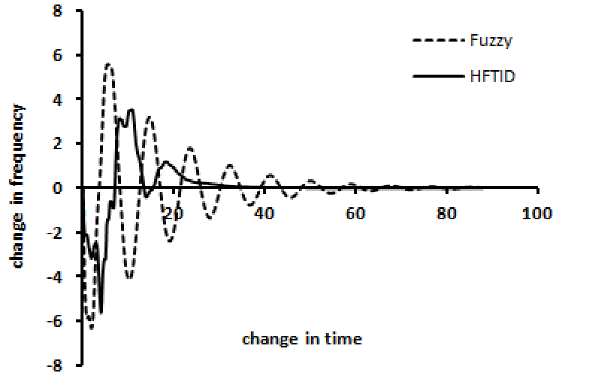

Fig. 21. Comparison of Frequency response of hydro system by using Fuzzy and HFTID controller.

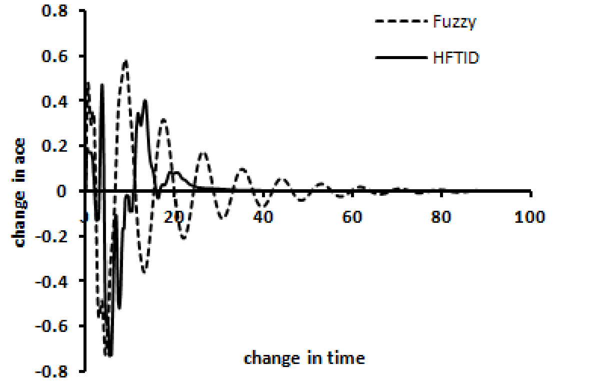

Fig. 22. Comparison of ACE response of hydro system by using Fuzzy and HFTID controller.

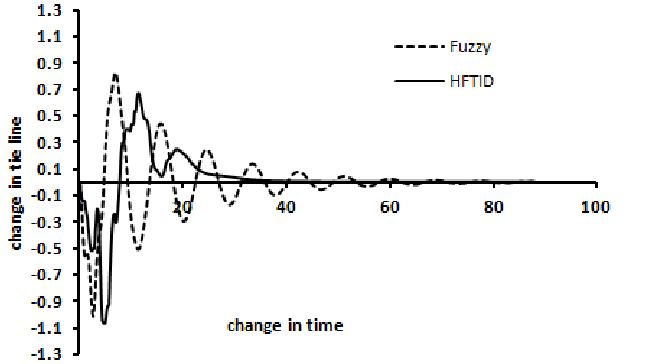

Fig. 23. Comparison of change in tie line power of reheat thermal - hydro interconnected system by using fuzzy and HFTID controller.

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TABLE II. Comparison between fuzzy and HFTID controller.

Fuzzy Logic Controller			HFTID Controller	
For .2 Step Change	Settling Time (Seconds)	Peak Overshoot	Settling time	Peak Overshoot
Thermal Power Plant	60	(-6 - 4.8)	40	(-4 – 2.9)
Hydro Power Plant	60	(-6.1 – 5.8)	38	(-5.7 – 3.3)

From the above results and comparison table it is clear that HFTID controller have better response then Fuzzy controller.

V. Conclusion

In this paper, different controllers has been studied namely Fuzzy and HFTID (Hybrid Fuzzy -Tilt Integral Derivative Controller) which is then applied to a reheat thermal – hydro interconnected system. This application is an alternative and successful control for LFC. Simulation studies have been carried out using MATLAB platform to study the transient behaviour of the system due to load perturbations. It is seen from the simulations that, the proposed HFTID controller causes less peak overshoots, improves the system performance as well as less settling time for the system to become stable as compared to Fuzzy controller. Simulation results establish the usefulness of the proposed controller for LFC.

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