

# Effect of HFTID Controller on the Stability of Thermal Power Generator

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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  $\pm 0.5$  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 HFTID controller on the stability of thermal Power generator. 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; load frequency control; HFTID

## I. INTRODUCTION

Energy plays a vital role in any country economy. Day by day the energy consumption is increasing very rapidly. The standard of living of a given country can be directly related to per capita energy consumption. In the present scenario, every country meets its energy needs from different sources available. Some major sources of energy are discussed below:-

Solar energy can be a major source of power because Sun's energy can be utilized as thermal and photovoltaic. When we talk about solar photovoltaic (SPV) applications this energy can be used in SPV lighting System, solar powered drives (Solar water pumping system, solar vehicles), building integrated photovoltaic (BIPV). But so far it could not be developed on a large scale due to certain limitations as it is expensive and installation cost is more, efficiency is very lesser, weather dependent and only available in day time.

Wind energy can be economically used for the generation of electrical energy. Wind energy can be utilized to run a wind mill, which in turn drives a generator to produce electricity. Wind energy had certain merits as discussed: due to the availability of wind everywhere in the world, the greatest advantage of electricity generation from wind is that it is renewable and not depleted with the use like fossil fuels; villages in remote area particularly in INDIA are still in dark. But due to this technology electricity can be provided in any remote area. But it has certain demerits also as discussed: this source of power is non-steady and unreliable as there are wide variations in speed and direction of winds, favorable winds are available only in few geographical locations. Hydro energy can also be a major source of power because water is available in abundant on earth. The kinetic energy of the moving stream while falling from the top end of the dam can be used to run a

turbine, which in turn drives a generator to produce electricity. Hydro energy had certain merits as discussed: Water Power is quite cheap where water is available in abundance and the operating costs of hydroelectric power plants are quite low. But it has certain demerits also as discussed: capital cost of hydro hydroelectric power plants is higher and it takes considerable long time for the erection of such plants.

Energy from fossil fuels can also be utilized to generate electricity like in thermal, nuclear and diesel power plants. In thermal power plant coal is burned to produce heat which in turn evaporates the water then through nozzle steam produced while coming out of the nozzle hits the turbine as the result turbine rotates which in turn drives the generator to generate electricity. Thermal power plants had certain merits as discussed: Overall capital cost is lesser than that for hydro plants, occupy less space compared to hydro and can be located very conveniently near the load centre. But it has certain demerits also as discussed: Maintenance and operating costs are high and the presence of environmental hazards due to dust and hot temp in the plant were also enormous. Power system operation considered so far was under the conditions of steady load. But in actual both active and reactive power demands are never steady they continually change with rising or falling trend of load demand. So, input to the generator (steam input to turbo-generators or water input to hydro-generator) must be continuously supplied to match the real power demand, if not as a result the machine speed will vary with consequent change in frequency which is highly undesirable (max. permissible change in frequency is  $\pm 0.5$  Hz). As manual regulation is not feasible, so automatic generation control as discussed in Section III for single area system and voltage regulation equipment must be installed on each generator, in order to reduce the problems of stabilization in power system which further improves the voltage and

frequency of supply within the permissible limits. 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) as discussed in equation (1)

$$u(t) = K_p e(t) + k_i \int_0^t e(\tau) d\tau \tag{1}$$

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

$$u(t) = K_p e(t) + k_i \int_0^t e(\tau) d\tau + K_d \frac{de}{dt} \tag{2}$$

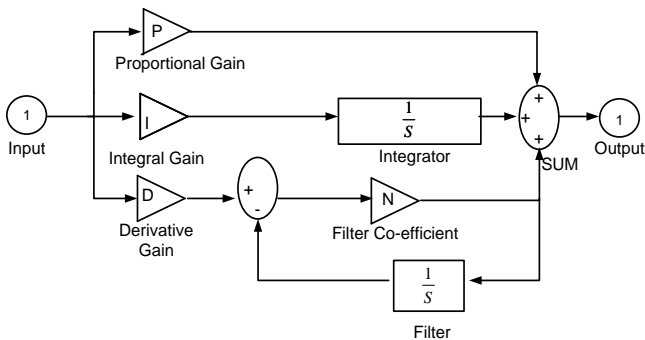


Fig. 1. Simulation model of PID controller.

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.

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.

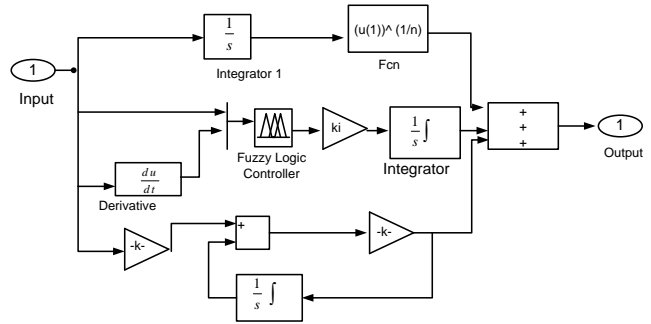


Fig. 3. Simulation model of HFTID controller.

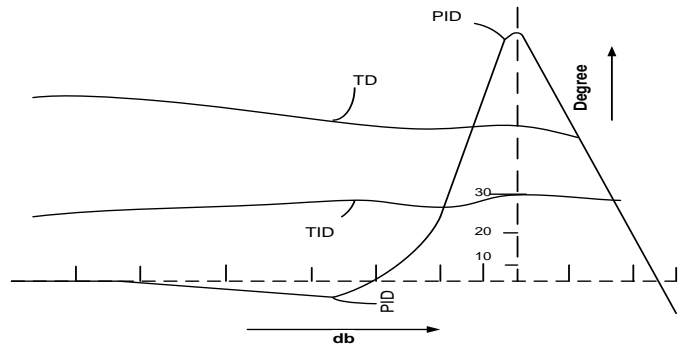


Fig. 4. Graphical representation of PID and TID.

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 thermal 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 damage it, but these issues can be prevented by the use of 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

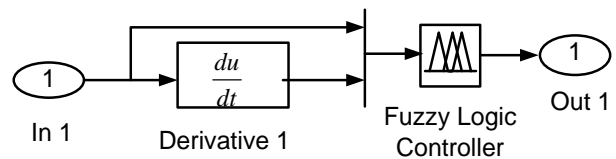


Fig. 2. Simulation model of FLC.

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 form 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 an independent power system, the main issue is not 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 single area is shown below in Fig. 5.

IV. METHODOLOGY

While performing Simulations on Thermal system with and without controller 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<sub>i</sub>) =2.4 Hz/per unit MW, Steam governor time constant (T<sub>g</sub>) =0.08sec, Reheat time constant (T<sub>r</sub>) =10.0sec, Reheat constant ( K<sub>r</sub>) =0.5sec, Inertia Constant

(H<sub>i</sub>)=5sec, Area rated power(P<sub>ri</sub>) =2000MW, Steam turbine time constant (T<sub>i</sub>) =0.3sec, D<sub>i</sub> =8.33\*10<sup>-3</sup> p.u. MW/Hz, T<sub>pi</sub>= 20sec, K<sub>pi</sub> = 120Hz.p.u./MW where T<sub>pi</sub>= 2H<sub>i</sub>/ f<sup>2</sup>D<sub>i</sub>, D<sub>i</sub> =ΔP<sub>D<sub>i</sub></sub>/Δf<sub>i</sub> K<sub>pi</sub> = 1/D<sub>i</sub>, ACE= Area Control Error, B<sub>i</sub>=Frequency bias factor, K<sub>d</sub>, K<sub>p</sub>, K<sub>i</sub> = Electric governor derivative, proportional and integral gains, respectively, i = Subscript referred to area.

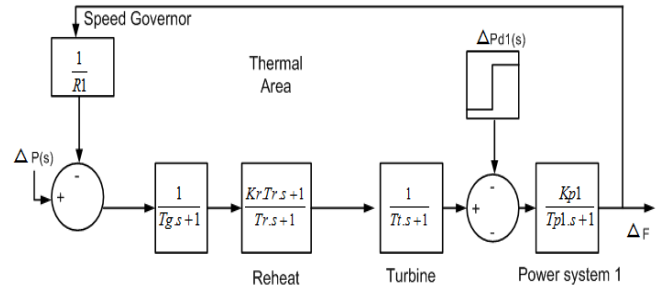


Fig. 5. Block diagram representation of isolated power system load frequency control.

The fuzzy logic controller block is designed by the combination of area control error ACE<sub>i</sub> and by the rate of change of area control error Δ ACE<sub>i</sub>. 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

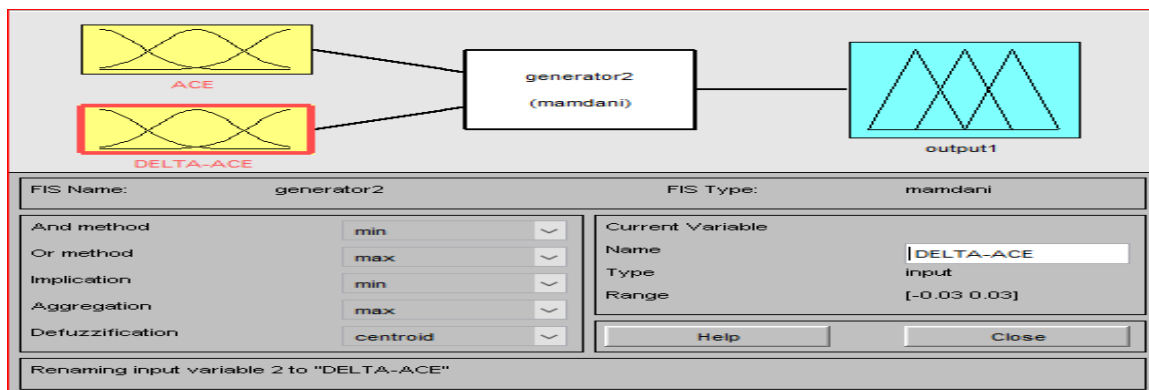


Fig. 6. Represents the I/Ps and O/Ps of the fuzzy logic controller.



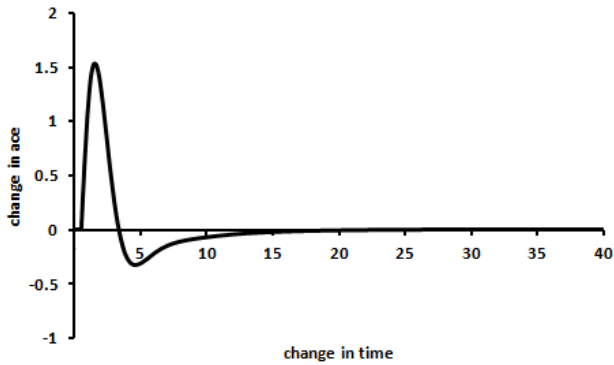


Fig. 12. ACE response of thermal system with HFTID controller.

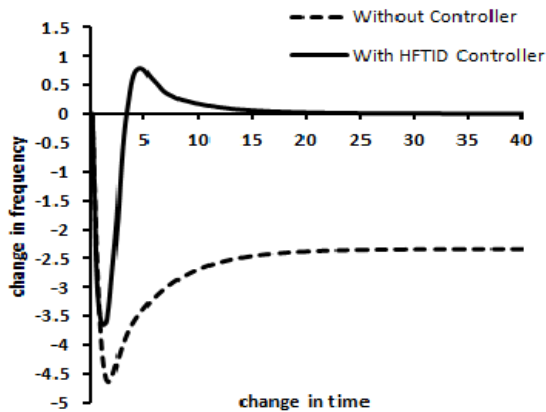


Fig. 13. Comparison of frequency response of thermal system with and without HFTID controller.

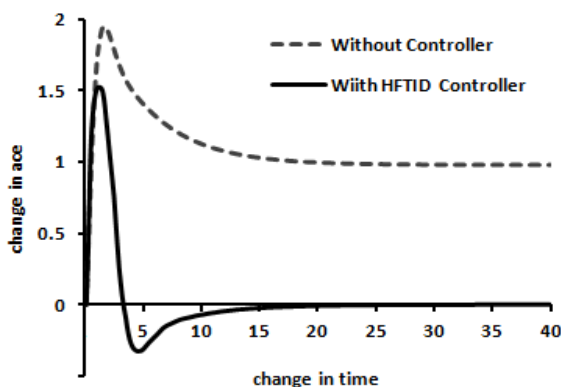


Fig. 14. Comparison of ACE response of thermal system with and without HFTID controller.

control error with .5 step change in load by using HFTID controller. Fig 13. and Fig. 14 shows the comparison of dynamic responses of the thermal system in the shape of frequency deviation and area control error with .5 step change in load. Table II shows the comparison of frequency responses of the thermal system with and without controller in the form of peak overshoots and settling time with .5 step change in load. Table III shows the comparison of area control error of the thermal system with and without controller in the form of peak overshoots and settling time with .5 step change in load. Table IV shows the best values for integrator and derivative controller after performing many simulations with .5 step change in load.

TABLE II. Change in frequency of thermal system.

|                        | without controller | with HFTID controller |
|------------------------|--------------------|-----------------------|
| maximum overshoot      | 0                  | 0.7                   |
| minimum overshoot      | -4.6               | -3.6                  |
| settling time (in sec) | 33                 | 26                    |

TABLE III. Change in area control error of thermal system.

|                        | without controller | with HFTID controller |
|------------------------|--------------------|-----------------------|
| maximum overshoot      | 1.96               | 1.5                   |
| minimum overshoot      | 0.9                | -0.36                 |
| settling time (in sec) | 34                 | 25                    |

## VI. CONCLUSION

In this paper, hybrid Fuzzy -tilt integral derivative controller (HFTID) is applied to power 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 controller causes less peak overshoots as well as less settling time for the system. Simulation results establish the usefulness of the proposed controller for LFC.

TABLE IV. Adjusting the values for integrator and derivative gain.

| S. No | 1/N | Integrator Gain |       | Derivative Gain |           | Response |
|-------|-----|-----------------|-------|-----------------|-----------|----------|
|       |     | Ki              | Kd1   | Kd2             |           |          |
| 1     | 2.9 | 10              | 1     | 3               | Very bad  |          |
| 2     | 2.8 | 5               | 0.9   | 0.8             | Bad       |          |
| 3     | 2.7 | 1               | 0.1   | 0.3             | Fine      |          |
| 4     | 2.6 | 0.5             | 0.09  | 0.29            | Good      |          |
| 5     | 2.5 | 0.2             | 0.001 | 0.009           | Very Good |          |
| 6     | 2.4 | 0.1             | 0.009 | 0.001           | Excellent |          |

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