ISSN (Online): 2456-5717
International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.4 Issue.3 March 2018

Comparative Analysis Between Fuzzy and PID Control for Load Frequency Controlled Power

Murumulla Vamsi[1], Mr. Rajesh Satti[2]
[1]PG Scholar, Department of Electrical and Electronics Engineering, Swamy Vivekananda Engineering College, Kalavarai, Vizianagaram, India
[2]Assistant Professor, Department of Electrical and Electronics Engineering, Swamy Vivekananda Engineering College, Kalavarai, Vizianagaram, India

***Abstract*— Steam turbine generation units are used in the power system especially for some special features of fossil-fuelled power plants. When a load disturbance occurred in the system, a frequency variation will cause a primary regulation action on generation units. The units will automatically adjust their outputs to fit for the new load demand. Variation of the governing valve position may exceed to the outlet pressure of the related boiler but boiler often has a long control time cycle after the pressure error was observed. Fuzzy PID controller is usually used to speed up the regulation procedure of boiler and to improve the stability of the steam parameters upstream of steam turbine. Model parameter identification is one of the most reliable tools to estimate the model parameters. In the proposed work, a general model of power plant with Fuzzy and Fuzzy PID control system is built for power system dynamic analysis. The model responses will be compared with Fuzzy and Fuzzy PID for system frequency stability.**

***Index Terms*— PID controller, Fuzzy control, Fuzzy PID control system, dynamic model, Parameter identification, power plant.**

I. INTRODUCTION

Steam turbine generation units are used in the power system for some special features of fossil-fuelled power plants. When a load disturbance occurred in the system, frequency variation will cause a primary regulation action on generation units. The units will automatically adjust their outputs to fit for the new load demand. Variation of the governing valve position may exceed to the outlet pressure of the related boiler but boiler often has a long control time cycle after the pressure error was observed. PID controller and FPID controller is usually used to speed up the regulation procedure of boiler and to improve the stability of the steam parameters upstream of steam turbine. Many researchers have studied the mathematic models of power plant for power system dynamic analysis. According to their research, low order models for turbine units are more popular for power system dynamic analysis. According to huge test experiences, single turbine model is not without a consideration of a main stream pressure variation. Boiler model is also needed for some circumstances. Control System of boiler and the PID controller and FPID controller acting on both the boiler and turbine systems will have great impact on the pressure stability even output power of turbine units. But these control systems are not well considered in relative research .In this paper, a fossil-fuel power plant model is presented with PID controller and FPID controller power system analysis. The model parameters are identified for a turbine coal fired generation unit. The model responses are compared to the model without PID controller and FPID controller model to evaluate the impact of PID controller and FPID controller model on system frequency stability. Frequency response models have received limited treatment in the literature. The basic concept of the model derived here is based on the idea of uniform or average frequency, where synchronizing oscillations between generators are filtered out, but the average frequency behaviour is retained. The synchronizing oscillations are**,** taken from the simulations of reference [l].We seek to average these individual machine responses with a smooth curve that can be used to represent the average frequency for the system. Such a filtered or average frequency**.**. Similar and related approaches have been pursued more recently **[**3, 4] through work on energy functions. The basic ideas are also important in the work on system Area control simulators [5, 6],as well as the work on long term dynamics [7, 8].In addition to these resources, certain ideas have also been adopted from the work on coherency based dynamic equivalents [9, 10**],** as well as the work on transient energy stability analysis. A Genetic Algorithm (GA) represents a heuristic search technique based on the evolutionary ideas of natural selection and genetics. Although randomized, using the historical information they direct the search into the region of better performance within the search space.

In this paper, the PID and FPID controller is developed and compared with respect to their overshoot or undershoot and settling time under various operating conditions for a two area steam turbine and boiler model.

II. MODELING OF STEAM TURBINE

In a steam turbine the stored energy of high temperature and high pressure steam is converted into mechanical (rotating) energy, which then is converted into electrical energy in the generator. The original source of heat can be a furnace fired by fossil fuel (coal, gas, or oil) or biomass. The turbine can be either tandem compound or cross compound. In a tandem compound unit all sections are on the same shaft with a single generator, while a cross compound unit consists of two shafts each connected to a generator. The cross compound unit is operated as one unit with one set of controls. The power output from the turbine is controlled through the position of the control valve*s*, which control the flow of steam to the turbines. The valve position is influenced by the output signal of the turbine controller. High Pressure (HP), Intermediate Pressure (IP) and Low Pressure (LP) are the different turbine sections. The turbine considered for study in this paper is reheating type .Reheating improves efficiency [8].The effects of steam chest; reheated and nonlinear characteristics of control valve are considered. The fraction of turbine power generated by intermediate section is assumed as negligible on base value

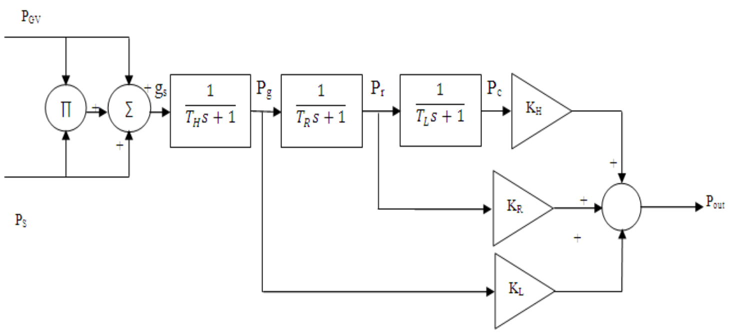

Fig.1 steam turbine model

Steam flow entered into steam turbine g_s is proportional to sum of the product of governing valve position variation P_{GV} and steam pressure variation of superheated Ps and two variations themselves. TH, TR and TL are time constants of three equivalent steam volume as high

ISSN (Online): 2456-5717

International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.4 Issue.3 March 2018

pressure volume, reheated volume and crossover volume, and Pg, Pr and Pc are average steam pressures of three volumes. Output power is a sum of output by three kinds of turbine cylinder. Power of each cylinder is considered to be proportion to its inlet steam pressure due to high pressure ratio. Relative with the rated output power the output portions of three cylinders are KH, KR and KL respectively.

III. PID CONTROLLER

One of the usual compensators that are widely used is PID controller. The combination of lead and lag compensators is used to achieve desired transient behaviour and low steady state error. The structure of this compensator that has been used in this study A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variables and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. The PID controller calculation algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted *P,I,* and *D.* Heuristically, these values can be interpreted in terms of time: *P* depends on the present error, *I* on the accumulation of past errors, and *D* is a prediction of future errors, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element.

In this tutorial we assume the controller is used in closed loop unity feedback system the variable de note the tracking error which is send to the PID controller. The controller single u form the controller to plant equal to the Proportional gain (K_P) time magnitude error gain Integral gain (k_I) time the integral of the time pulse the Derivative gain (K_D) times the derivative of the error.

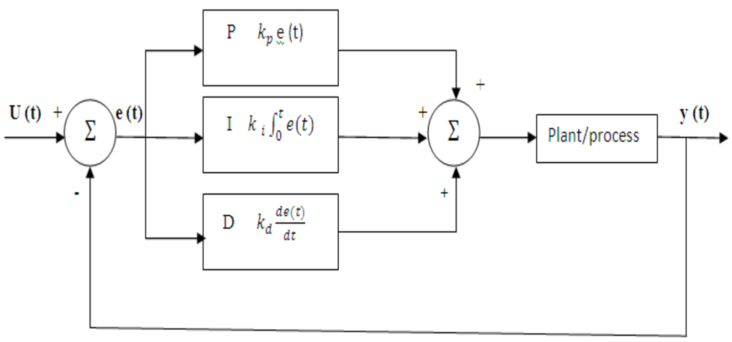

Fig.2 Block diagram of a PID controller

IV. FUZZY PID CONTROLLER

Although it is possible to design a fuzzy logic type of PID controller by a simple modification of the conventional ones, via inserting some meaningful fuzzy logic IF- THEN rules into the control system, these approaches in general complicate the overall design and do not come up with new fuzzy PID controllers that capture the essential characteristics and nature of the conventional PID controllers. Besides, they generally do not have analytic formulas to use for control specification and stability analysis. The fuzzy PID controllers to be introduced below are natural extensions of their conventional versions, which preserve the linear structures of the PID controllers, with simple and conventional analytical formulas as the final results of the design. Thus, they can directly replace the conventional PID controllers in any operating control systems (plants, processes). The conventional design of PID controller was somewhat modified and a new hybrid fuzzyPID controller was designed. Instead of summation effect a mamdani based fuzzy inference system is implemented. The inputs to the mamdani based fuzzy inference system are error and change in error.The main difference is that these fuzzy PID controllers are designed by employing fuzzy logic control principles and techniques, to obtain new controllers that possess analytical formulas very similar to the conventional digital PID controllers.

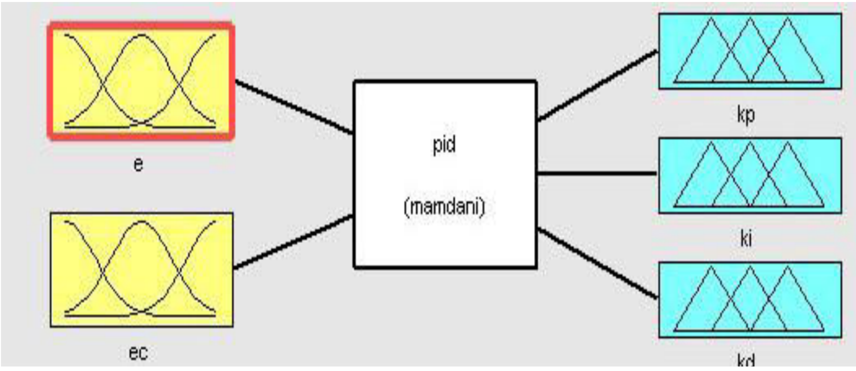

Fig.3 Fuzzy Inference System Editor Fuzzy PID Controller

TABLE 1: RULE TABLE FOR FPID CONTROLLER

	e	ec	K_p	K_i	K_d
1	PB	PB	PB	ZO	ZO
2	PB	PS	PB	ZO	PS
3	PB	ZO	PB	ZO	ZO
4	PB	NS	PB	ZO	PS
5	PB	NB	PB	ZO	ZO
6	PS	PB	PM	PS	PS
7	PS	PS	PM	PS	PS
8	PS	ZO	PB	ZO	PM
9	PS	NS	PB	ZO	PS
10	PS	NB	PB	ZO	PS
11	ZO	PB	PM	PS	ZO
12	ZO	PS	PM	PS	PS
13	ZO	ZO	PM	PS	PM
14	ZO	NS	PM	PM	PS
15	ZO	NB	PB	PM	ZO
16	NS	PB	PB	PM	ZO
17	NS	PS	PM	PM	PS
18	NS	ZO	PM	PM	PB
19	NS	NS	PM	PM	PS
20	NS	NB	PB	PM	ZO
21	NB	PB	PB	ZO	ZO
22	NB	PS	PB	ZO	PS
23	NB	ZO	PB	ZO	PB
24	NB	NS	PB	ZO	PS
25	NB	NB	PB	ZO	PS

V. TWO AREA STEAM TURBINE MODEL SIMULATIONS RESULTS

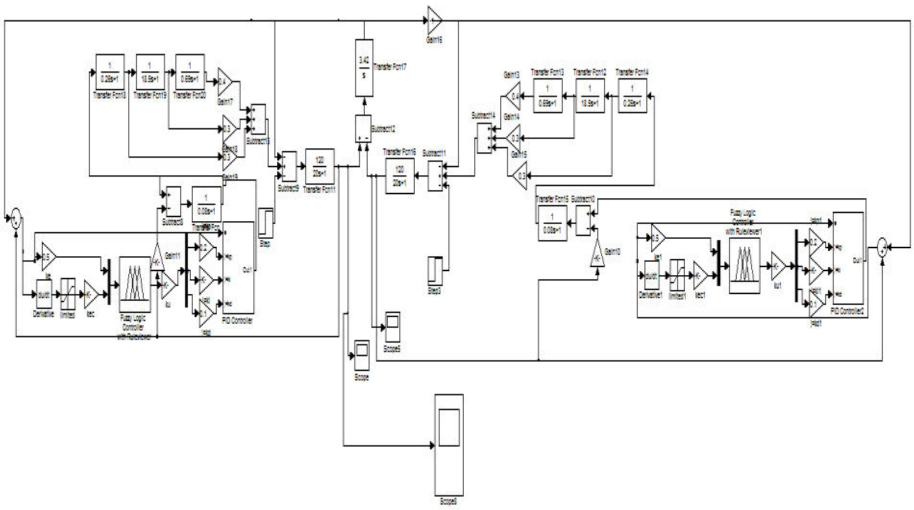

Fig.4 Two Area system with Fuzzy controller

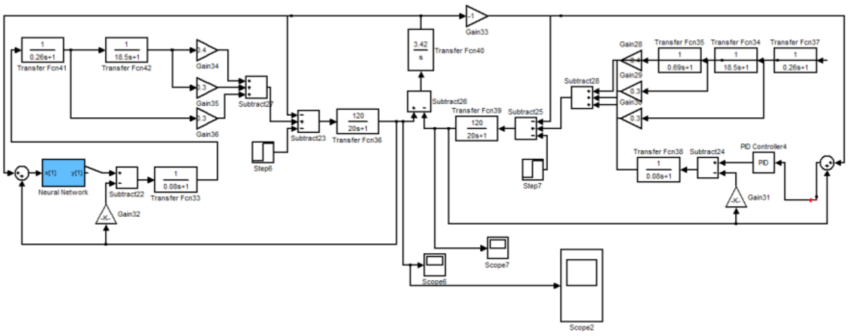

Fig.5 Two Area system with Fuzzy PID Controller

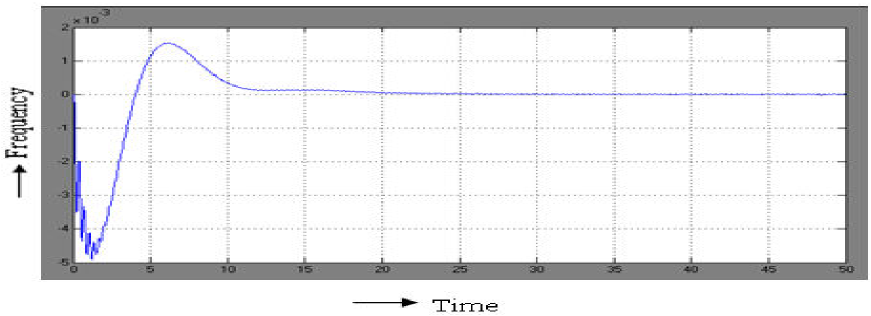

Fig.6 Frequency response with Fuzzy controller

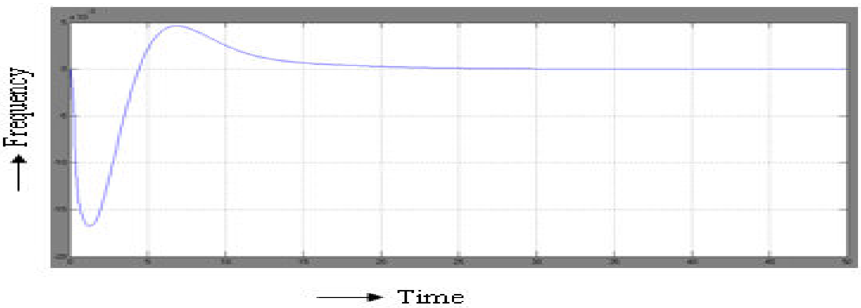

Fig.7 Frequency response with Fuzzy PID controller

In the above graphs firstly, a step load disturbance occurs in two areas (area1&area2) with step load increasing of 0.03p.u. With the use of a PID controller with a step load disturbance of

0.03p.u rise time has been reduced to 0.32s, settling time to 9.97 and overshoot is reduced to 137.With the use of a fuzzy PID controller with a step load disturbance of 0.03p.u rise time has been reduced to 0.3s, settling time to 9.97 and overshoot is reduced to 125.2.

A. Steam turbine model:

The steam turbine is mostly large power reheat units. There are multi low pressure cylinders and even multi intermediate pressure cylinders. The intermediate pressure cylinders can be considered as for the dynamic analysis.

T_H High pressure temperature
T_R Reheat temperature
T_L Lower pressure temperature

Table 2: Time constant value for turbine model

T_H	0.26s
T_R	18.5s
T_L	0.69s

VI. CONCLUSIONS

For supplying stable and reliable electric power, load frequency control is an important issue in power system operation and control. Automatic load frequency control is used to maintain the generator power output and frequency within the prescribed values. In this work the two area load frequency controller is considered. The simulated study shows the frequency response and steady state response of two area systems by using fuzzy and fuzzy PID.

The fuzzy is compared with fuzzy PID. Two similar areas are given with a disturbance of 0.05p.u. The simulation study shows that the stability of the system improved the frequency response and less settling time and steady state responses. Hence from the results we conclude that the Fuzzy PID is said to be better compensating then fuzzy controller.

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