Conventional-PID and GA-PID Based Comparative Analysis of Co-ordinated PID-UPFC Stabilizer

[1]Ravi Prakash Mahobia, [2]Mahesh Singh, [3]Shimpy Ralhan
[1]PG-Student, [2]Associate Prof., [3]Associate Prof.
Electrical and Electronics Department
[1]Shri Shankaracharya Group of Institutions, Bhilai, India

Abstract : ***In this paper Conventional-PID (CPID) and Genetic Algorithm (GA) Optimization are used for the tuning of Proportional-Integral-Derivative (PID) controller to design the coordinated PID-UPFC based stabilizer. These two are generally used to tune the PID controller parameters. The proposed method is easy to implement and provides better stability. The proposed work is done in MATLAB software. Basically, in this paper compare these CPID and GA-PID on the basis of waveform, settling time and maximum overshoot. When comparison is done, it is found that the performance of GA-PID is better than the performance of CPID. GA-PID controller gives better stability, improves steady state error and time required for rise of signal that is rise time, is also minimized. Simulation result shows fast response of GA-PID controller.***

IndexTerms - *Genetic Algorithm, Maximum Overshoot, Proportional- Integral- Derivative, Stability, Settling Time.*

I. INTRODUCTION

The demand of electric power is increasing day by day, as the population is increasing and with the advancement of technology [1]. It is necessary to maintain this demand with the power generation. The generation should be surplus the demand. Due to this power system is becoming the more and more complex [2]. To achieve this condition certain criterion should be there, for maintaining the demand and generation. These criterions are related to improve the power transfer capability and security of the system. It covers the area from the sending and to the receiving end that means from the generating station to the load station. In olden days, it is only related to the generating side and transmission. The main aim is to transfer the maximum amount of power from generation end to the load end. Increasing in the demand of power requires the increase in the transmission capability or construct new system [3], [4]. Existing line capability can be increased by reducing the line reactance by connecting the parallel lines at olden days [5]. Transmission line capability also increased by improving the active power transfer, reducing the reactive power, improving the power factor, improving the voltage of line. These has been done by the different equipment separately. Above all terms are concisely related to the stability. The word stability comes from the existence of synchronous machines [6]. The term stability is considered after being subjected to the disturbance [7]. The stability of the synchronous machine is the ability to recover its synchronism. The factor, that affects the stability are active, reactive power, power factor, voltage and impedance also. As the technology of semiconductor is increasing day by day, the control of the power system parameter is becoming easy day by day. The power system parameters variation is achieved by fast acting power electronics devices or FACTS devices [8]. FACTS devices are widely used in the power system now a days such as STATCOM, SSSC, IPFC, UPFC etc. In FACTS device, UPFC is best among all the devices [9]. The UPFC is most versatile and complex device [10]. The UPFC in its general form can provide simultaneous, real-time control of all basic power system parameters or combinations of that parameters, and this can be done without any hardware alterations in the UPFC [11]. This is the reason behind selecting the UPFC over STATCOM, SSSC and any other FACTS devices. In this paper, UPFC is controlled only to study the comparison of speed deviation, with the CPID and GA-PID at transient condition. The result of comparison of simulated waveforms are shown for two machine system connected through double circuit line and grid.

II. BASIC FUNCTION OF UPFC

The basic function of the UPFC is control the flow of power in transmission line. A basic schematic diagram of UPFC is shown in Fig. (1) below. It has two converters, which are connected through the two transformers. These converters are named as series converter and another one is shunt converter, and the transformers are known as series transformer and shunt transformer, those are connected to line and converter respectively. The two converters are connected through the common DC link. It may have the battery bank or group of capacitors as per the required rating, that has to be control. The UPFC can control all most all parameters of transmission line such as active power, reactive power, power angle, line impedance. Generally, it is done by maintaining the power flow control in the transmission line. The shunt converter provides the required amount of power to the series converter and vice versa. Through this, active and reactive power flow can be maintained, the impedance can be maintained by adjusting the series injection voltage proportional to the line current so that the series transformer appears as an impedance, when viewed from then line. All this done by taking the reference parameters. One can control all the parameter as per the need. In this paper only speed deviation is concerned, for analyzing the stability of the two machine power system, and the respected waveforms are shown for the two machine system [12].

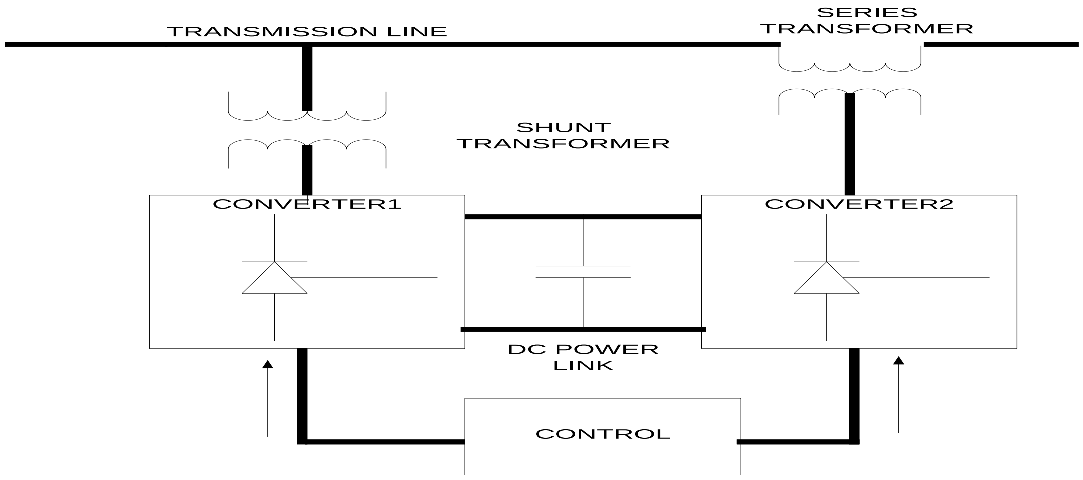

Fig .1 Basic Structure of UPFC

III. PROPORTIONAL- INTEGRAL- DERIVATIVE CONTROLLER

The PID controllers are vastly used controller in industrial purpose. PID controller parameters are tuned to get the desired output from the plant. PID is generally a feedback controller. The plant output signal is feed back to control the output.

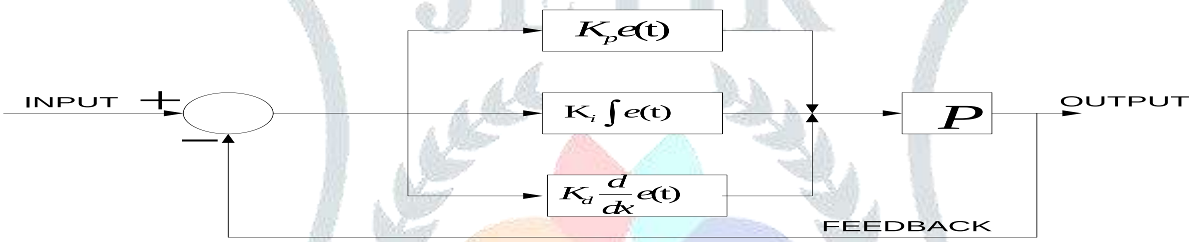

Fig.2 Basic Block Diagram of PID Controller

It has the error signal e(t), which is nothing but the difference between desired input and output. Fig. (2) shows the basic PID controller block diagram, where P is the Plant [13]. The transfer function of the PID controller is shown below:

$$u(t) = K_p e(t) + K_i \int e(t) + K_d \frac{d}{dx} e(t) \qquad \text{....(1)}$$

Where, K_p = Proportional gain.

K_i = Integral gain.

K_d = Derivative gain.

These gains have different effect on rise time, maximum overshoot, settling time and steady state error as shown in Table.1 below.

Table.1 Effect of Gain on Different Parameter of Signal

Gain	Rise Time	Maximum Overshoot	Settling Time	Steady-State Error
Kp	Decrease	Increase	Small- Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small-Change	Decrease	Decrease	Small Change

IV. ERROR MINIMIZATION TECHNIQUE

The feedback system has very important function to minimize the error to zero as soon as possible. Hence, some standard is used to find attribute of the system response [14]. The common criterions are given below:

1. **Integral of Absolute Error (IAE)**

$$\mathrm{IAE} = \int_0^\infty |e(\mathrm{t})|\,dt$$

2. **Integral of Square of Error (ISE)**

$$ISE = \int_0^\infty e^2(\mathrm{t})dt$$

3. **Integral of Time Multiplied by Absolute Error (ITAE)**

$$ITAE = \int_0^\infty t\,|e(\mathrm{t})|\,dt$$

4. **Integral of Square of Time Multiplied by Error (ITSE)**

$$ITSE = \int_0^\infty te^2(\mathrm{t})dt$$

in this work ''Integral of time multiplied by absolute error'' is used.

V. TWO MACHINE SIX BUS SYSTEM

The two machine six bus power system is comprising of two-hydraulic power plants connected to a power grid. Complete two machine six bus system is shown in Fig. 2. The UPFC is connected to improve the improve the stability in a 500/230 kV transmission line. The power system used under the study is assembled in a loop arrangement, and it is a combination of five buses (B1, B2, B3, B4, B5). Three lines L1 to L3 are connected to make a ring system. Each plant having their own PSS, excitation system and speed regulators. The UPFC is connected to the bus 3 via line 1-2 to control both the power in the system and the voltage at the bus B_UPFC using two VSCs via dc link capacitor and the coupling reactors and the through transformers. The total generating capacity of 1500 MW, one grid is of 1500 MVA, 500 kV and 200 MW load. In this model two machines are connected by the double circuit line; whose voltage is at 230kV. The length of the line is 65 km between them and bus 1 is connected beside the double circuit line (left side). The two machine six bus is taken with the fault (after the 65 km double circuit line) between machine-1 (G_1) and machine-2 (G_2). Two algorithms and conventional tuning are used. Where G_1, G_2, G_3 are the Machine (generator)-1, Machine (generator)-2 and Grid respectively.

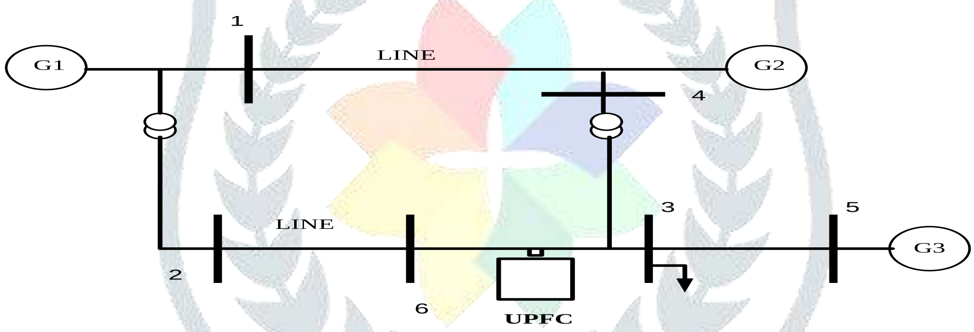

Fig. 2 Two Machine Six Bus System

VI. PROPOSED METHODOLOGY

Genetic algorithm (GA) is an adaptive method used to solve optimization problems. As per concept of fittest function in year 1989 a probabilistic method was proposed by Goldberg. It is the method by which global search and optimization is done and which is done by evolution and natural selection. The factor that affects GA is only objective function as well as corresponding fitness levels. Fig. 6 shows flow chart of GA. GA is the method in which global search and optimization is done by evolution and natural selection [15].

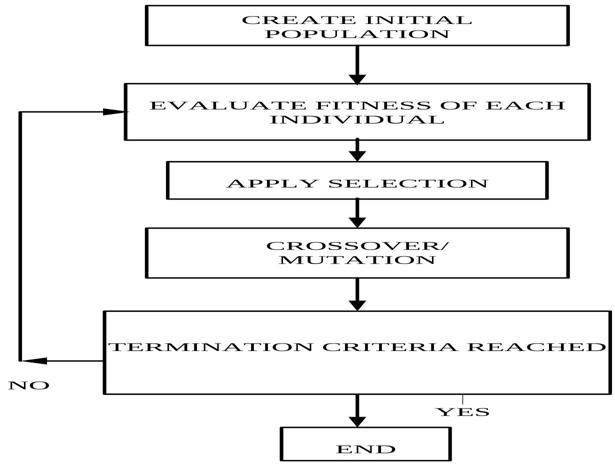

Fig. 3 Flow Chart of GA

VII. RESULT

The results under three phase fault condition with coordinated UPFC-PID controller are shown below. Here the comparison is done on the basis of speed deviation graph. Two waveforms for each machine (CPID and GA-PID). Where CPID is Conventional PID. Three conditions are shown here at first, when two machine are connected and in second when only one machine is connected.

(i) When both the machines (G_1 and G_2) are connected in the system:

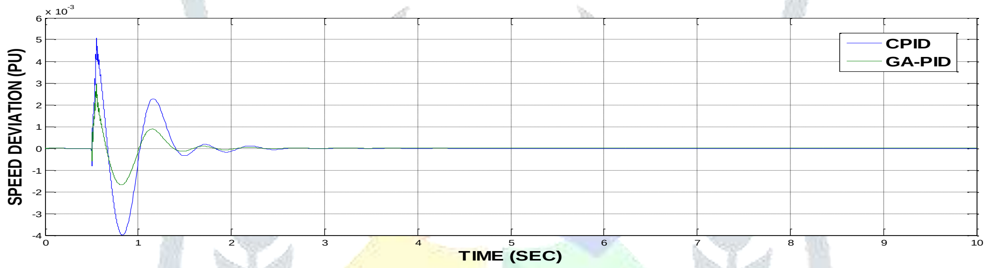

Fig. 4 Comparison of Speed Deviation of Machine-1

Fig. 4 shows the result of speed deviation of machine-1, under faulty condition. Where x-axis represents the time in second and y-axis represents speed deviation in pu. According to the waveform, system gets stable in GA-PID faster than CPID. In GA-PID Speed deviation reaches to a zero value in lesser. Table-2 shows the settling time and maximum overshoot of the speed deviation in the form of comparison table, which also says that GA-PID is better.

Table.2 Settling Time and Maximum overshoot of the Speed Deviation of Machine-1

Parameter	CPID	GA-PID
Settling Time(sec)	**2.5**	**2**
Maximum overshoot Time(pu)	**$5x10^{-3}$**	**$3x10^{-3}$**

Fig. 5 shows the result of speed deviation of Machine-2 under faulty condition. Where x-axis represents the time in second and y-axis represents speed deviation in pu According to the waveform system gets stable faster in GA-PID as compare to the CPID. Steady state condition reaches first in GA-PID. Table-3 shows the settling time and maximum overshoot of the speed deviation in the form of comparison table, which also says that GA-PID is better.

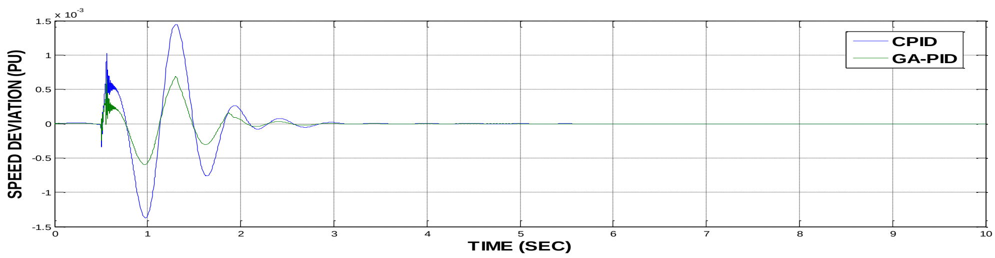

Fig. 5 Comparison of Speed Deviation of Machine-2

Table.3 Settling Time and Maximum overshoot of the Speed Deviation of Machine-2

Parameter	CPID	GA-PID
Settling Time(sec)	3	2.3
Maximum overshoot Time(pu)	$1.4x10^{-3}$	$0.7x10^{-3}$

Table-2 shows the settling time and maximum overshoot of the speed deviation in the form of comparison table, which also says that GA-PID is better.

(ii). When only Machine-1(G_1) is connected in system:

In this condition at a time only one machine is connected. Fig. 6 shows the condition when only machine-1 is connected to the system similarly Fig. 7 shows the graph when only machine-2 is connected to the system.

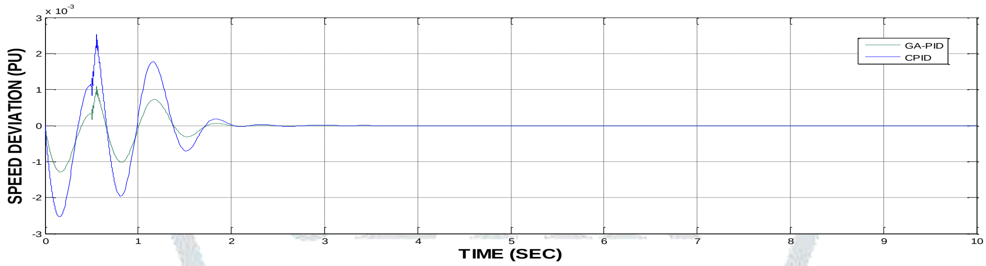

Fig. 6 Comparison of Speed Deviation of Machine-1

Table.4 Settling Time and Maximum overshoot of the Speed Deviation of Machine-1

Parameter	CPID	GA-PID
Settling Time(sec)	3	2
Maximum overshoot Time(pu)	$2.5x10^{-3}$	$1x10^{-3}$

Fig. 6 shows the result of speed deviation of Machine-1 under faulty condition. There is no machine-2 in the system. In graph x-axis represents the time in second and y-axis represents speed deviation in pu. According to the waveform system gets stable in GA-PID faster than CPID. Speed deviation in GA-PID reach to a zero value in lesser time. From the table 4, it is clear that GA-PID performance is better from the CPID for Machine-1.

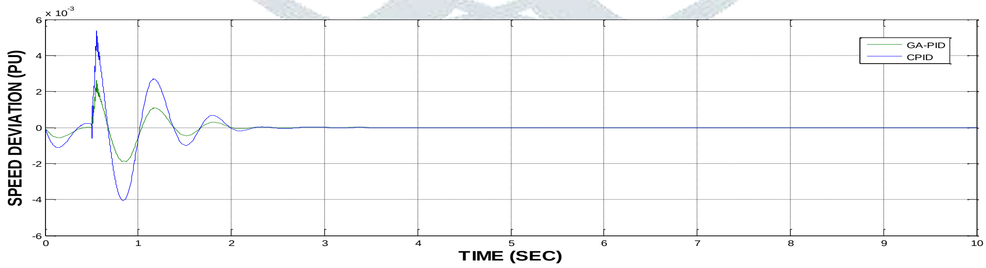

Fig. 7 Comparison of Speed Deviation of Machine-2

Table.5 Settling Time and Maximum overshoot of the Speed Deviation of Machine-2

Parameter	CPID	GA-PID
Settling Time(sec)	2.6	2.2
Maximum overshoot Time(pu)	$5.7x10^{-3}$	$2.6x10^{-3}$

Above Fig. 7 shows the waveform of machine-2, in this condition only machine-2 is connected in the power system and machine-1 is disconnected from the system. In graph x-axis represents the time in second and y-axis represents speed deviation in pu. Also, in this condition GA-PID gives faster response then CPID. Table-5 shows the settling time is 2.6 and 2.2 respectively for CPID

and GA-PID, whereas maximum overshoot of the speed deviation is 5.7*10-3 and 2.6*10-3 respectively for CPID and GA-PID, that means performance of GA-PID is better than CPID.
In this paper, it is found that overall performance of the GA-PID is better than the CPID, that are shown in the graph as well as from the table also. The settling time and maximum overshoot of all the speed deviation signal is less in case of the GA-PID and more in CPID.

VIII. Conclusion

In this paper the performance of CPID and GA-PID of coordinated PID-UPFC is analyzed. It has been analyzed in MATLAB platform. Basically, both controllers improve the stability of proposed power system, which is two machine system. Here only speed deviation is concerned, UPFC can control approximately all the parameters of transmission line like active power, reactive power, power angle, impedance of line. The rise time, maximum overshoot, steady- state error is minimized in both the cases of proposed controller, and when it is compared with the each other, then it is found that, the performance of the GA-PID is better than the CPID, in terms of all the parameters stated above, that is rise time, maximum overshoot, steady state error. So, the stability caused by the GA-PID is more than the CPID. The time required to reach zero error is less in case of GA-PID and more in CPID. So, the overall performance of GA-PID is better than the CPID. The analysis can also be done with the control parameter of UPFC such active and reactive power, power angle and impedance.

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