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Exploring of GA based IPFC for Elimination of Oscillations

ABSTRACT
A genetic algorithm (GA) is a learning algorithm that imitates the evolution of organisms. Genetic Algorithm(GA) is a search technique which is used to find exact or approximate solutions to optimization and search problems. The pair of six pulse converters are connected in transmission line series for voltage injection. The firing signals are generated with help of GA based tuning of IPFC. Simulation results are tested on simple model with power oscillations damping controller (POD). The effective control signals for IPFC performance has been tested in MATLAB environment.

***Keywords**- IPFC, GA.*

I. INTRODUCTION

From the last few decades, power demand has significantly increased. However, this growing power demand is not pursued by enhancing the power generation and transmission capacity. Low frequency oscillations in the system threat to stability of the grid. Therefore, the steady state stability is necessary to address for grid security.

By using FACTS devices maximum benefits of transmission system can be managed. The voltage source converter based reactive power compensation well tested for fine control.The pair of static synchronous series compensators known as IPFC identified as more effective power flow controller in large power system network. Segundo et al [11] have focused on fast and smooth reactive power compensation.

Dhurvey et al [13] have investigated the PI based IPFC in comparison with fuzzy based IPFC. Parimi, et al [12] have applied the Fuzzy logic based IPFC. Dhurvey et al [24] described new control strategy of multi-line power flow. However, they have not discussed the method for obtaining the optimized GA based IPFC. This paper presents the optimization of IPFC parameters Kp and Ki using Genetic algorithm approach to achieve the reduced oscillations under small disturbance.

II. ANALYSIS

Multi-line control as in Fig.1 with series transformers.

Δm_{v1} and Δm_{v2} are voltage magnitudes similarly $\Delta\beta_1$ and $\Delta\beta_2$ are the change in phase angles displayed in Appendix-A.

III.INTERLINE POWER FLOW CONREOLLER

The simplification applied in power system model by neglecting resistance and transients of line and transformers [19].

$$\dot{\delta} = \omega_0(\omega - 1) \tag{1}$$

$$\dot{\omega} = \frac{P_m - P_e - P_D}{M} \tag{2}$$

$$\dot{E}_{fd} = \frac{-E_{fd} + K_a(V_{ref} - V_t)}{T_a} \tag{3}$$

$$\dot{V}_{dc} = \frac{3m_{v1}}{4C_{dc}}(\cos\beta_1 I_{1d} + \sin\beta_1 I_{1q}) + \frac{3m_{v2}}{4C_{dc}}(\cos\beta_2 I_{2d} + \sin\beta_2 I_{2q}) \tag{4}$$

$$V_{se1d} = -x_{t1}I_{1q} + \frac{V_{dc}}{2} m_{v1}\cos\beta_1 \tag{5}$$

$$V_{se1q} = -x_{t1}I_{1d} + \frac{V_{dc}}{2} m_{v1}\sin\beta_1 \tag{6}$$

$$V_{se2d} = -x_{t2}I_{2q} + \frac{V_{dc}}{2} m_{v2}\cos\beta_2 \tag{7}$$

$$V_{se2q} = -x_{t2}I_{2d} + \frac{V_{dc}}{2} m_{v2}\sin\beta_2 \tag{8}$$

A linearizing IPFC model at is operating point [26].

$$\dot{\Delta\omega} = \frac{(\Delta P_m - \Delta P_e - D\Delta\omega)}{M} \tag{9}$$

$$\dot{\Delta\delta} = \omega_0 \Delta\omega \tag{10}$$

$$\Delta \dot{E}_q^1 = \frac{(-\Delta E_q + \Delta E_{fd})}{T_{do}^1} \tag{11}$$

$$\Delta\dot{E}_{fd} = \frac{-\Delta E_{fd} + K_a(\Delta V_{ref} - \Delta V_t)}{T_a} \tag{12}$$

$$\Delta\dot{V}_{dc} = K_7\Delta\delta + K_8\Delta E_q^1 - K_9\Delta V_{dc} + K_{cmv1}\Delta m_{v1} + K_{c\beta1}\Delta\beta_1 + K_{cmv2}\Delta m_{i2} + K_{c\beta2}\Delta\beta_2 \tag{13}$$

Where,

$$\Delta P_e = K_1\Delta\delta + K_2\Delta E_q^1 + K_{pv}\Delta V_{dc} + K_{pmv1}\Delta m_{v1} + K_{p\beta1}\Delta\beta_1 + K_{pmv2}\Delta m_{v2} + K_{p\beta2}\Delta\beta_2 \tag{14}$$

$$\Delta E_q = K_4\Delta\delta + K_3\Delta E_q^1 + K_{qmv1}\Delta m_{v1} + K_{q\beta1}\Delta\beta_1 + K_{qmv2}\Delta m_{v2} + K_{q\beta2}\Delta\beta_2 + K_{qv}\Delta V_{dc} \tag{15}$$

$$\Delta V_t = K_5\Delta\delta + K_6\Delta E_q^1 + K_{vv}\Delta V_{dc} + K_{vmv1}\Delta m_{v1} + K_{v\beta1}\Delta\beta_1 + K_{vmv2}\Delta m_{v2} + K_{v\beta2}\Delta\beta_2 \tag{16}$$

The updated Phillip linear model of the small system with IPFC installed displayed in Fig.2. Operating conditions are described by choosing K_1 to K_9 is taken from [26]. The state-space representation of model as-

$$\dot{X} = AX + BU \tag{17}$$

$$x = \begin{bmatrix} \Delta\delta & \Delta\omega & \Delta E_q^1 & \Delta E_{fd} & \Delta V_{dc} \end{bmatrix}^T \tag{18}$$

$$u = \begin{bmatrix} \Delta m_{v1} & \Delta m_{v2} & \Delta\beta_1 & \Delta\beta_2 \end{bmatrix} \tag{19}$$

$$A = \begin{bmatrix} 0 & \omega_0 & 0 & 0 & 0 \\ -\frac{K_1}{M} & \frac{-D}{M} & -\frac{K_2}{M} & 0 & -\frac{K_{pv}}{M} \\ -\frac{K_4}{T_{do}^1} & 0 & -\frac{K_3}{T_{d0}^1} & \frac{1}{T_{do}^1} & -\frac{K_{qv}}{T_{do}^1} \\ -\frac{K_aK_5}{T_a} & 0 & -\frac{K_aK_6}{T_a} & -\frac{1}{T_a} & -\frac{K_aK_{vv}}{T_a} \\ K_7 & 0 & K_8 & 0 & -K_9 \end{bmatrix} \tag{20}$$

$$B = \begin{bmatrix} 0 & 0 & 0 & 0 \\ \frac{-K_{pmv1}}{M} & \frac{-K_{p\beta1}}{M} & \frac{-K_{pmv2}}{M} & \frac{-K_{p\beta2}}{M} \\ \frac{-K_{qmv1}}{M} & \frac{-K_{q\beta1}}{M} & \frac{-K_{qmv2}}{M} & \frac{-K_{q\beta2}}{M} \\ \frac{-K_aK_{vmv1}}{T_a} & \frac{-K_aK_{v\beta1}}{T_a} & \frac{-K_aK_{vmv2}}{T_a} & \frac{-K_aK_{v\beta2}}{T_a} \\ K_{cmv1} & K_{c\beta1} & K_{cmv2} & K_{c\beta2} \end{bmatrix} \tag{21}$$

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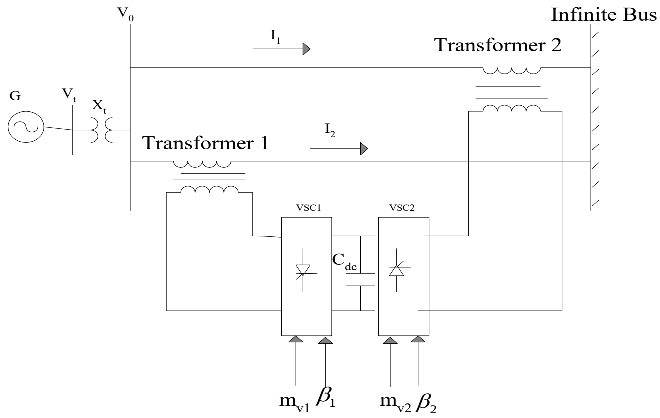


Fig. 1. Simple power system with IPFC

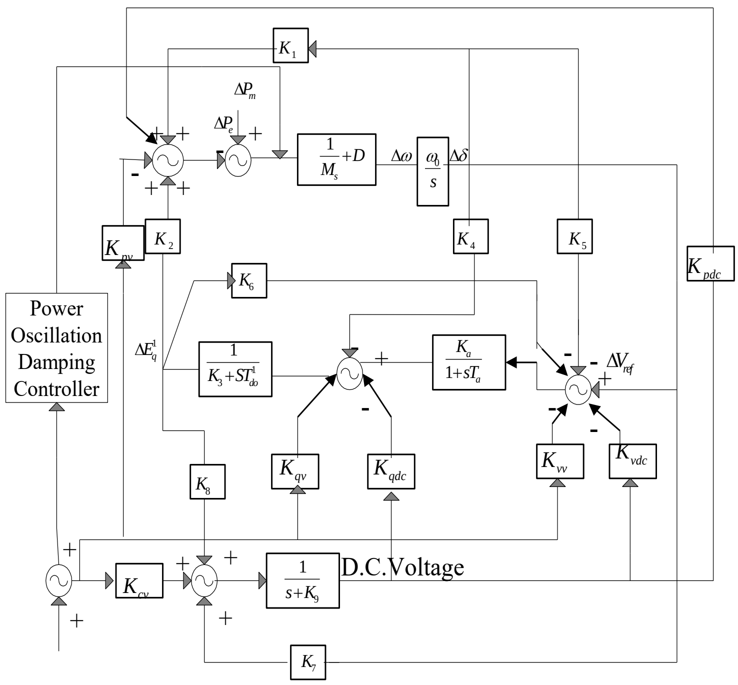


Fig. 2. Linear Model of IPFC

IV.INTEGRATED TUNING OF POD AND IPFC

In this part, implementation of auxiliary suppression signal Power Oscillation Damping Controller (POD has been done for up gradation in PI controller performance as exhibited in Fig. 3. The POD controller [19] shown in section 2 consists of K_{DC}, $\frac{sT_\omega}{1+sT_\omega}$ and $\frac{1+sT_1}{1+sT_2}$. To obtain finest damping execution, best values of parameters of T_1 and T_2 are chosen.

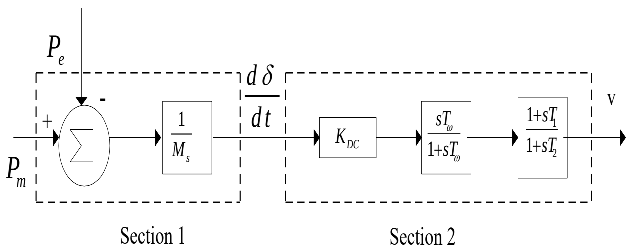
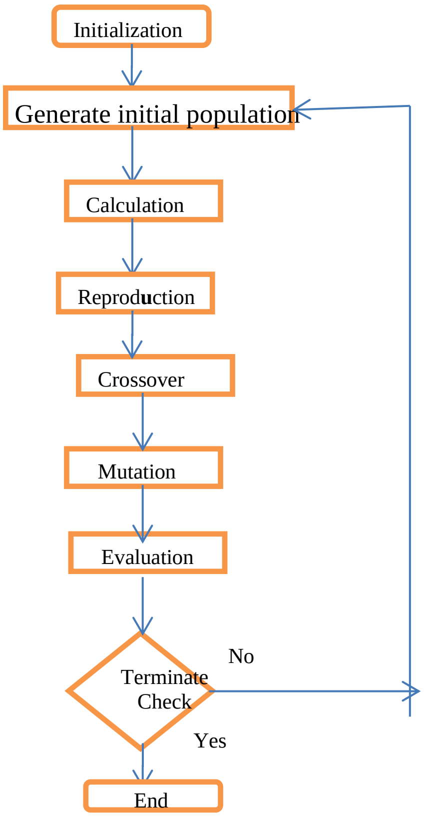


Fig. 3. Power Oscillation Damping (POD)Controller

V. GENETIC ALGORITHM BASED CONTROLLER

The details of GA steps and procedure is shown in Fig. 4.



Fig, 4. Flowchart of Genetic Algorithm

Table 1: GA Parameters

No. of variables	03
Best Fitness Value	0.00158312
Objective function value	0.0015831210794886197
Generation	300
Iterations	300

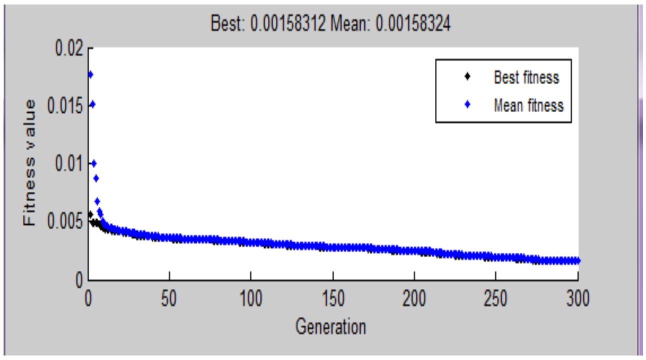


Fig. 5. Fitness function

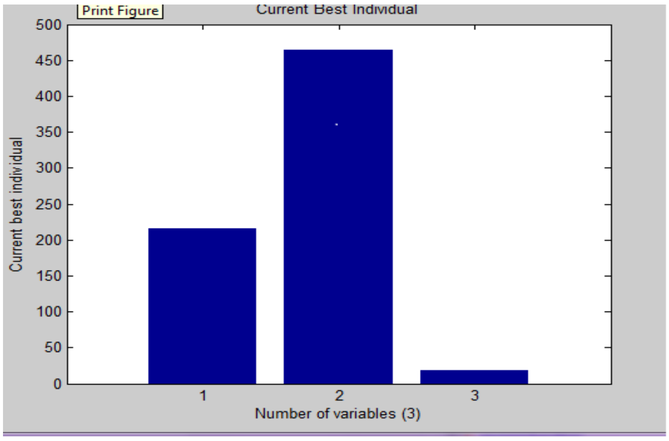
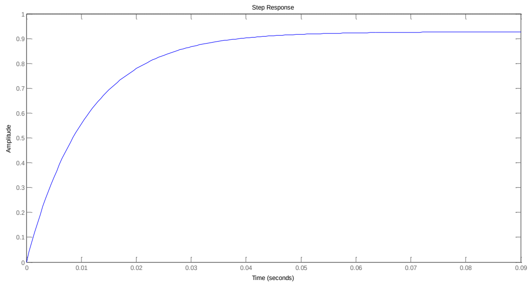


Fig. 6. Best Individual



Fig, 7. Step Response

VI. SMALL SIGNAL ANALYSIS

In MATLAB environment, analysis of four damping signals with 10% change in mechanical power input has been done with

a. With POD

b. With GA

A. Effective execution with firing signal m_{v1}

Simulation in Fig**.** 8 shows that as compared to POD GA performance is upgraded in which peak of speed deviation is reduced from 16 $\times 10^{-3}$ to 14 ×10-3rad/sec
and settleled in less time of 20sec. clarified by Table 2.

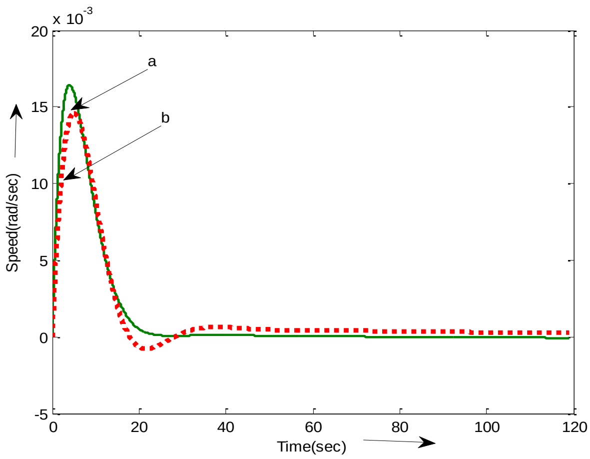


Fig. 8. Control signal response of control signal m_{v1}

Table 2: Eigen value analysis with firing signal

m_{v1} with POD	m_{v1}+GA
-53.4042 +32.3424i	-33.9013 +43.5686i
-4.2221	-4.4148
-1.0577 + 2.4857i	-1.0577 + 2.4857i

-0.0730	-0.0815
-0.0279	-0.0309

B. Effective realization with firing signal m_{v2}

In Fig. 9, with control signal m_{v2}, when K_p and K_i are optimized with GA, peak of speed deviation is reduced from 0.022 to 0.017sec, settles in less time of 40sec. shows the excellent output.

Table 3 shows the roots of system on s-plane developed for IPFC with POD, IPFC with GA.

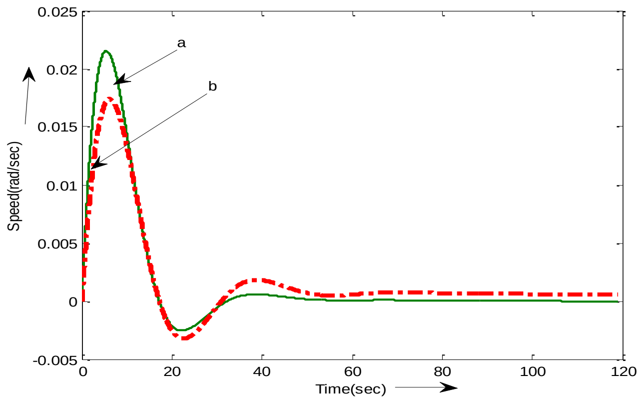


Fig. 9: Response of signal m_{v2}

Table 3: Roots of control signal m_{v2}

m_{v2} with POD	m_{v2} with GA
-28.3940 +44.3029i	-20.4493 +45.0165i
-5.0295	-5.2933
-1.0577 + 2.4857i	-1.0577 + 2.4857i
-0.0890	-0.0936
-0.0321	-0.0332

C. Effective execution with firing signal β_1

From Fig. 10, IPFC with signal β_1, when K_p and K_i are optimized with GA, oscilattions are effectively reduced, peak of speed deviation is reduced from 8 ×10-3 to 7 ×10-3sec simulation response is drastically updated

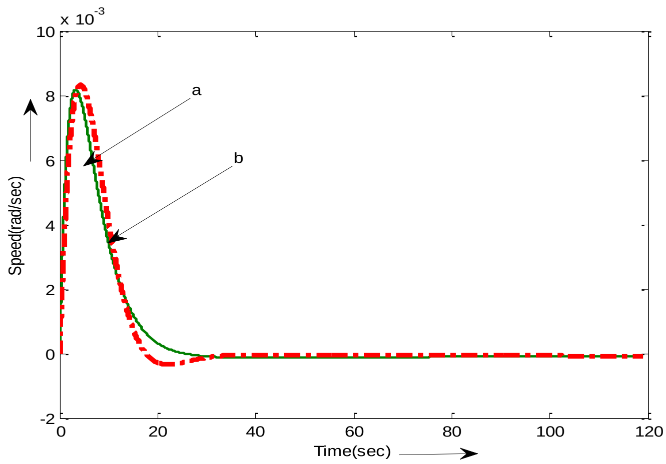


Fig. 10. Speed deviation response of control signal β_1

Table 4 Eigen value indicates that system is stable, settling time reduced from 50 to 40 sec. because roots are lying on negative half of s-plane.

Table 4: Small signal analysis of simple system with signal β_1

β_1 with POD	β_1 with GA
-99.2811	-45.2119 +39.8063i
-49.9138	-3.9868
-4.0941	-1.0577 + 2.4857i
-1.0577 + 2.4857i	-0.0775
-0.0721	-0.0235
-0.0178	

D. Effective execution with firing signal β_2

Response of IPFC with optimized GA shown in Fig. 11. It indicates that deviation reduces substantially from 0.035 to 0.025sec .

All the negative values shown in Table 5 prove the stability of the system.

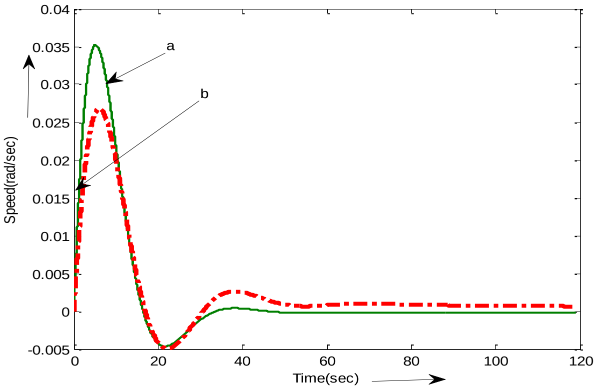


Fig. 11: Speed deviation response of control signal β_2

Table 5: Eigen value analysis simple system with firing signal β_2

β_2 with POD	β_2 with GA
-29.8316 +45.0741i	-21.2000 +45.6294i
-4.0792	-4.0385
-1.0577 + 2.4857i	-1.0577 + 2.4857i
-0.0783	-0.0859

Table 6: Time domain attainment for all modes

	With POD			With GA		
	No. of Oscillations	Peak of speed deviation (rad/sec)	Settling Time (sec)	No. of Oscillations	Peak of speed deviation (rad/sec)	Settling Time (sec)
m_{v1}	2	16 $\times 10^{-3}$	30	1	14 ×10-3	20
m_{v2}	2	0.022	50	1	0.017	40
β_1	2	8 ×10-3	30	1	7 ×10-3	20
β_2	2	0.035	50	1	0.025	40

VII. CONCLUSION

Precise path for evaluating relative strength of IPFC firing signals for suppressing low frequency oscillations has been presented. Combined effect of updated model of GA based IPFC with Power Oscillation Damping has been studied. IPFC firing signals m_{v1} and β_2 shows vigorous achievement. Validity of time domain analysis has been done with Eigen value analysis under alteration of various firing signals which verifies the performance of various IPFC control strategy. . Optimized results of firing signals m_{v1} and β_2 shows that oscillations are well suppressed.

VIII. ACKNOWLEDGEMENT

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