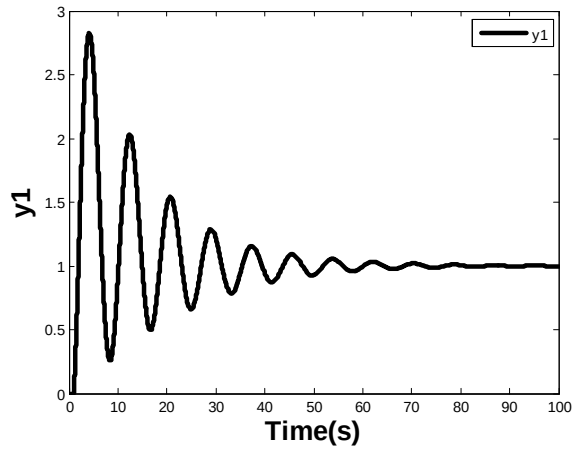
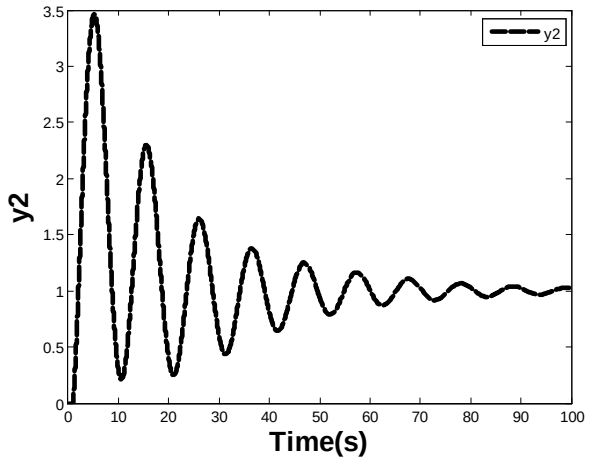


(a)



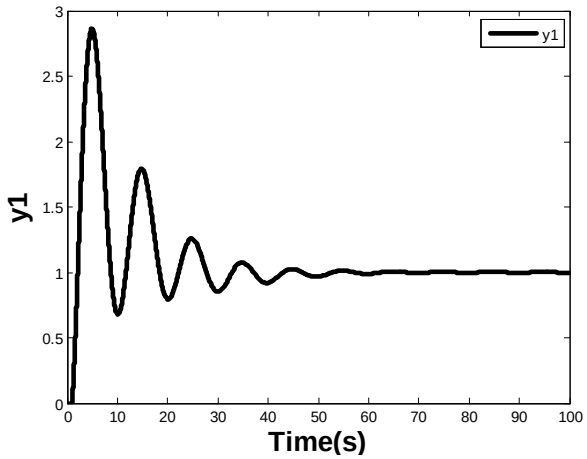
(b)

Figure 4 (a) & (b): Response of PI controllers with decouplers using Particle Swarm Optimization for a step input in y1 and y2 separately**.**

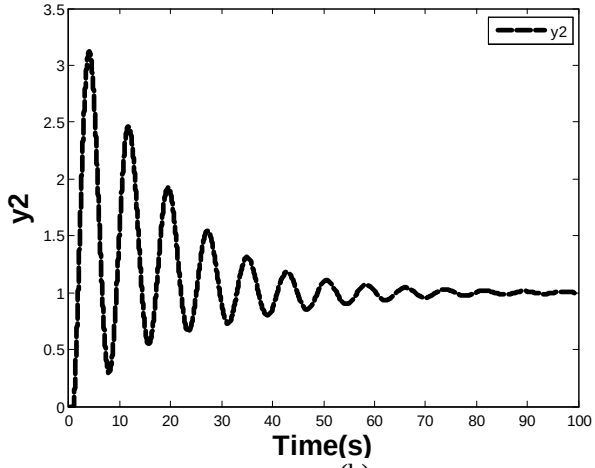
The Performance criteria like IAE and ISE values are tabulated in Table 1. And the response is showed in the figure 4 (a) and (b).

D. Firefly Algorithm

The convergence of the Firefly Algorithm (FA) towards finding the optimum controller parameters is presented [14]-[15], [24].



(a)



(b)

Figure 5 (a) & (b): Response of PI controllers with decouplers using Firefly Algorithm for a step input in y1 and y2 separately**.**

A stable response is obtained for the controller values K_{P11}=-1.1706, k_{I11}=-0.0897, k_{P22}=-1.2650, k_{I22}= -0.0650. And this heuristic algorithm produces less value of IAE and ISE when compared to above controller design methods. The outputs y_1 and y_2 response are shown separately in the figure 5 (a) and (b).

5. Performance Analysis

The Performance of the controller are evaluated using performance criteria like IAE, ISE. Integral Absolute Error (IAE) is a trade-off between both and generally gives better response and Integral Square Error (ISE) is used for suppressing large errors. The PI controller was designed for the given process and the controller design procedure is carried out using the heuristic methods, such as Particle Swarm Optimization (PSO), Firefly Algorithm and also using ETF's model and Direct Synthesis. By evaluating the values of IAE and ISE, Firefly Algorithm has lower value than other controller design used in this paper.

Table 1: Performance analysis for an example

Sl. No.	*Performance Criteria*		*ETF*	*DS*	*PSO*	*FA*
1	IAE	Y1	26.1	17.14	18.46	15.62
		Y2	39.08	24.05	31.24	23.38
2	ISE	Y1	19.74	17.71	14.44	14.65
		Y2	36.48	30.99	31.47	21.1
3	OVER	Y1	2.897	2.925	2.82	2.86
		Y2	3.428	3.5	3.46	3.12
4	SETTLING	Y1	130	70	80	60
		Y2	160	97	120	94

6. Conclusion

In this paper, PI controller with decoupler for Two-Input Two-Output system is designed using Firefly Algorithm. Better results were obtained using FA when compared to conventional methods such as ETF and Direct Synthesis method and heauristic method like PSO. Using Firefly Algorithm, the performance criteria such as IAE, ISE values are low when compared to other methods.

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