I J C T A, 9(17) 2016, pp. 8765-8771

Design of a Hybrid Damping Controller for a Two Area System

Priyanka Kar* and Sarat Chandra Swain*

ABSTRACT

In order to achieve reliable power along with profit from the existing power system, they must operate closer to their stability limit. Stability limit measures the ability of the existing power system in different dimensions. This paper aims to damp the power oscillations in multi-machine power system. A static synchronous series compensator is used in between two area system which takes care of the power profile in the transmission line. The compensator has a PID controller structure. Here a firefly algorithm mutated with a harmony search algorithm is used for the calculation of the optimized controller parameters. To prove the effectiveness of the suggested controller, the performance is tested with standard FA and different test conditions.

Keywords: Static synchronous series compensator (SSSC), Flexible AC transmission system (FACTS), Harmony searches (HS), Firefly algorithm (FA), Proportional-Integral-Derivative (PID) controller.

I. INTRODUCTION

Power system reliability is one of the major areas of concern for today's power engineers. They have to target for healthy and wealthy power network for consumer and producer. So the flexible AC transmission system incorporated into the power system market [1]. A SSSC is a FACTS device used in series to improve the transmittable power capacity. The input signal to the SSSC plays a vital role in deciding the controller parameters. Among the different type of stability SSSC contributes major for damping power oscillation [6].

This paper considers a two area three machine network along with SSSC [2]. The voltage injected in series from the SSSC is modulated through a PID controller structure. The controller parameters are calculated by using a hybrid optimization technique. Here a harmony search-firefly algorithm is used which is explained in the later sections [7].

II. POWER SYSTEM STRUCTURE

Figure 1 shows a three machine power system. The system has three synchronous machines. A tie-line connects the two areas. Area 1 has Generator G1 and area 2 has G2 and G3.

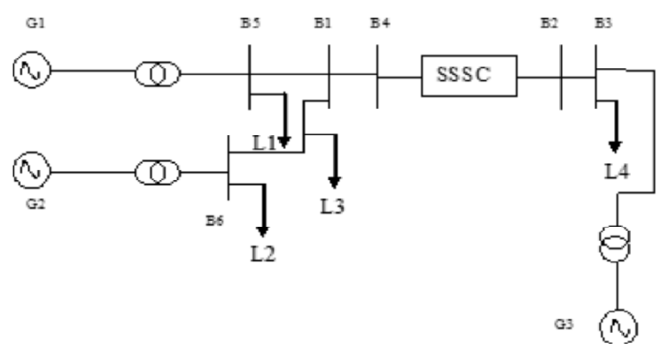

Figure 1: A three machine power system with SSSC

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Speed of generator G1, G2 and G3 changes during dynamic condition [5]. Let Δw1, Δw2 and Δw3 are the speed deviations for G1, G2 and G3 respectively. Then Δw2- Δw3 is taken as local mode of oscillations and Δw1-Δw2, Δw1- Δw3 are taken as the inter area mode of oscillations. The damping controller has a PID structure as shown in Figure 2 [4].

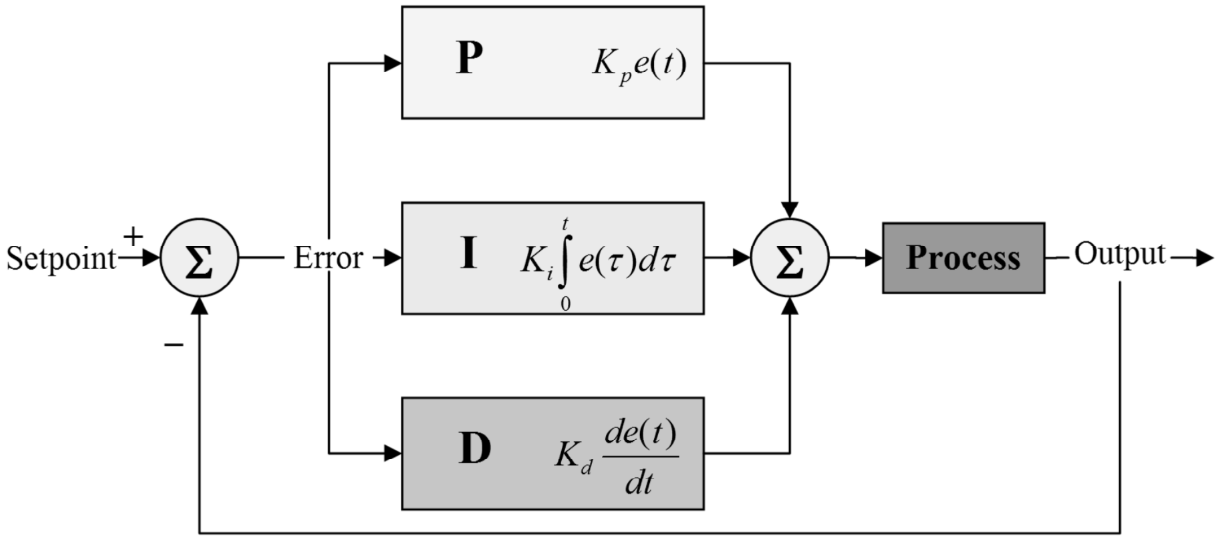

Figure 2: Structure of PID controller

III. HS-FA ALGORITHM

In this hybrid algorithm the harmony search algorithm explore the search space and the firefly algorithm exploit the solution reducing the complexity [3]. It selects some brightest firefly to form KEEP i.e. top fireflies. If KEEP is equal to the number of fireflies then it works like standard firefly algorithm. If KEEP is very small it leads to premature convergence. So here KEEP = 2.

In standard FA if intensity of I^{th} firefly is less then intensity of J^{th} firefly then it move towards J^{th} firefly and update the intensity [8]. If not then I^{th} firefly does nothing. In this hybrid algorithm the worst firefly is improved by mutation process following the rules in harmony search algorithm. Figure 3 shows the flowchart of a HS-FA algorithm.

3.1 Problem Formulation

In the present study speed deviation of the generator G1 and G3 is taken as the input signal to both the controller. So the objective function J is the integral time absolute error (ITAE) of the summation of the local and inter area mode of oscillations and is expressed as:

$$J = \int_{t=0}^{t=tsim} \left(\Sigma\,|\,\Delta w_L\,| + \Sigma\,|\,\Delta w_I\,|\right) t, dt$$

Where ΔW_L = speed deviation of local modes of oscillations

ΔW_I = speed deviation of inter-area modes of oscillations

t_{sim} = time period during which simulation is carried out

Hence the optimization problem for the present study can be designed along with the constraints on the controller parameter as follows:

Minimize J
Subject to

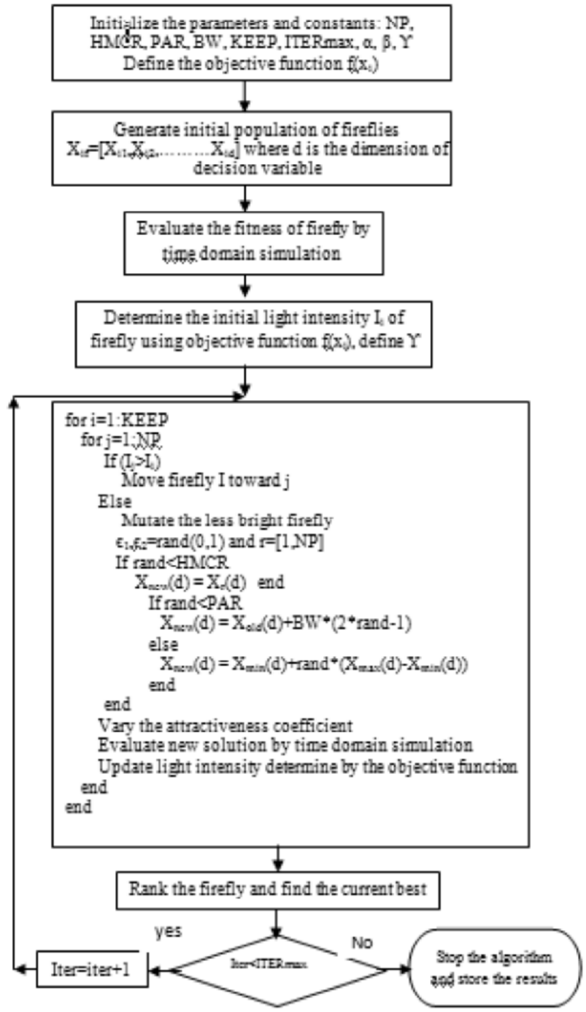

Figure 3: Flowchart of HS-FA algorithm

$$K_{pmin} <= K_p <= K_{pmax}$$
$$K_{dmin} <= K_d <= K_{dmax}$$
$$K_{imin} <= K_i <= K_{imax} \quad (2)$$

3.2 Implementation of HS-FA

HS-FA is used to optimize the controller parameters for a population size of 10 and generation of 10. The optimized PID controller parameters are listed in Table 1.

Table 1
PID controller parameters

Technique	K_p	K_i	K_d
Standard FA	15.0795	0.0592	0.0961
HS-FA	42.5889	0.0188	0.0242

IV. RESULTS

The simulation diagram of Figure 1 is shown in Figure 4. A three phase fault is applied in between bus 2 and 3 at 1 sec. The response of the system is shown for without controller, with standard FA based controller [9] and with HS-FA based controller in Figure 5 to 9.

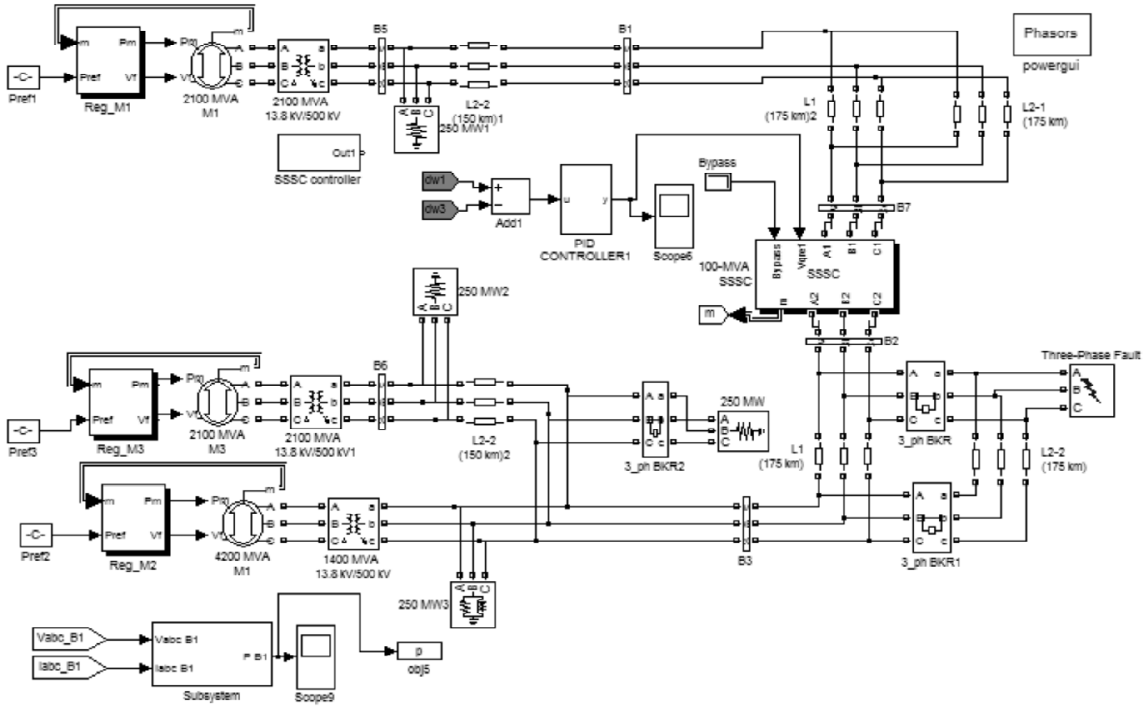

Figure 4: Simulation model

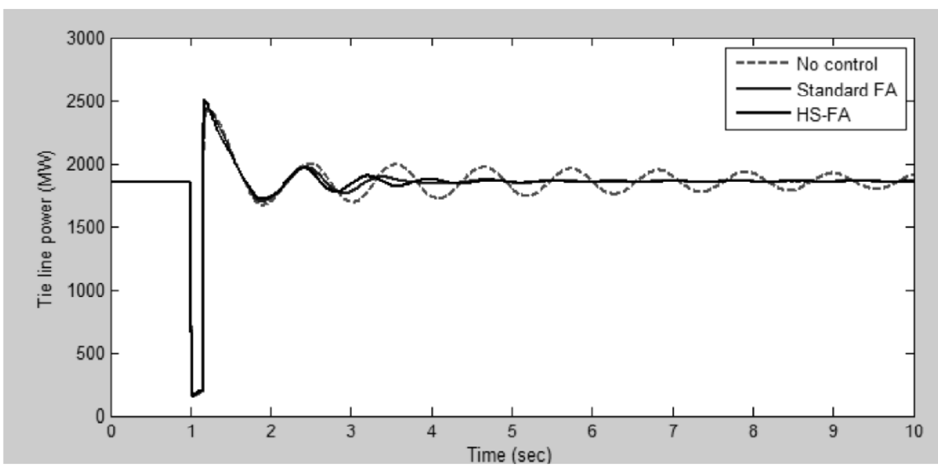

Figure 5: Tie-line power for three phase fault

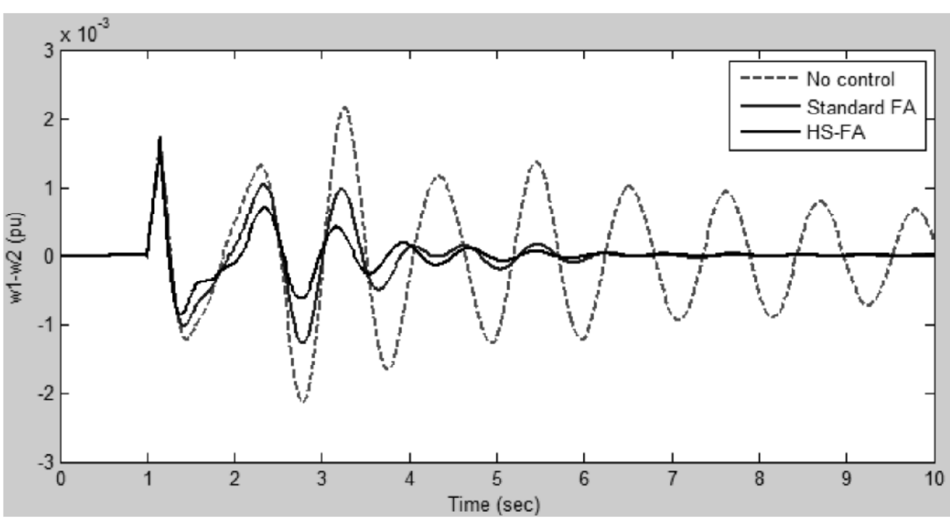

Figure 6: Inter area mode of oscillation w1-w2 for three phase fault

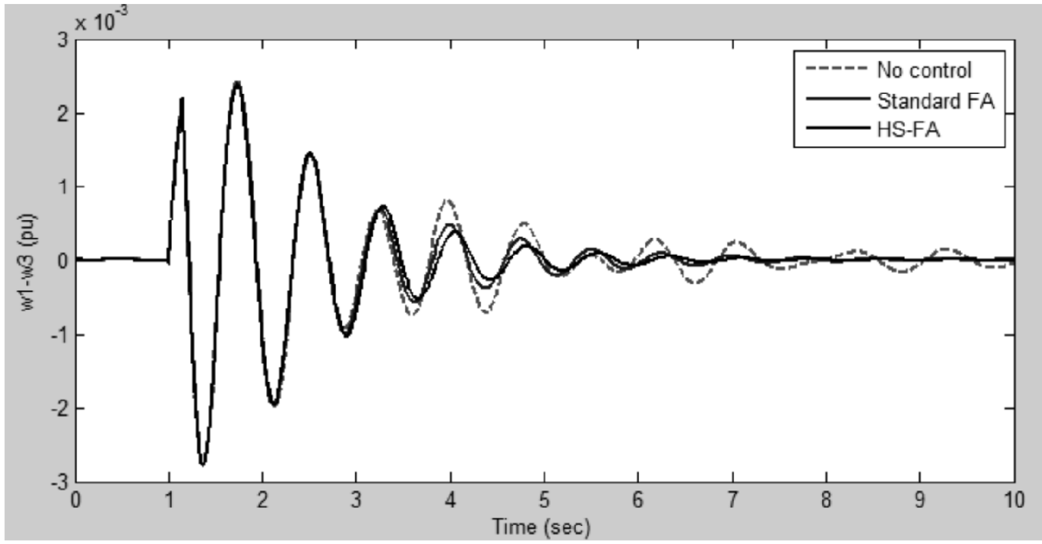

Figure 7: Inter area mode of oscillation w1-w3 for three phase fault

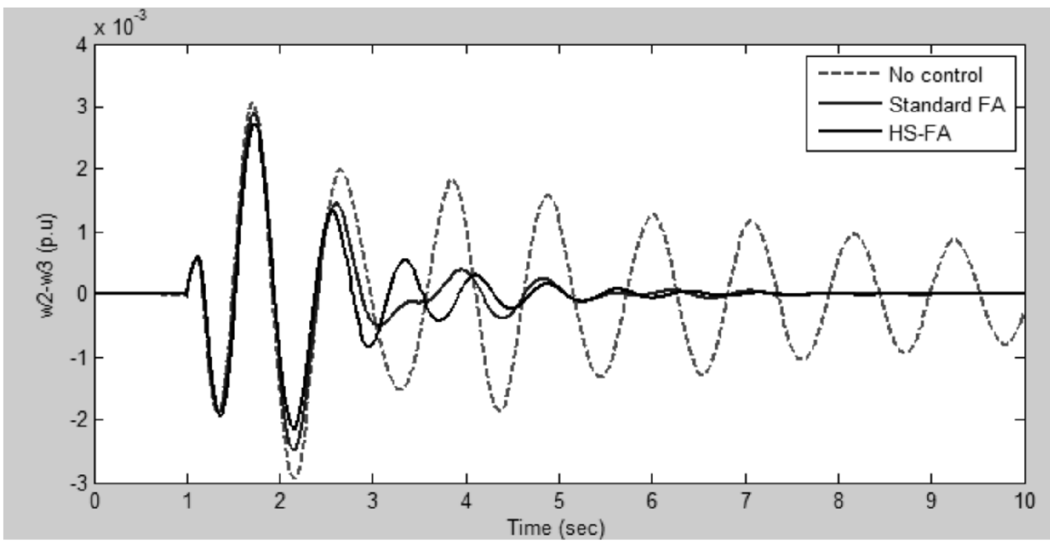

Figure 8: Local mode of oscillation w2-w3 for three phase fault

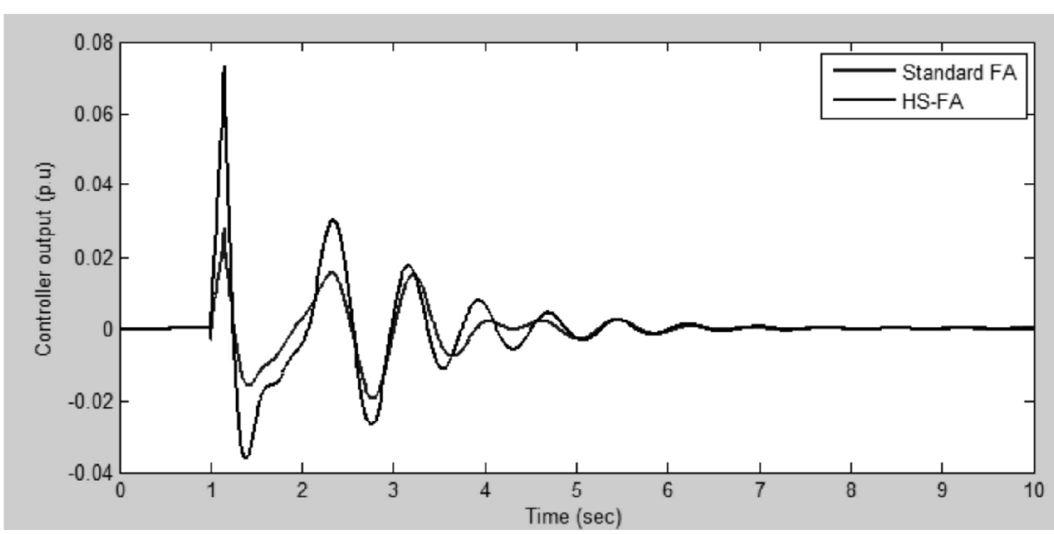

Figure 9: Controller output for three phase fault

(B) Case 2

A two phase fault is applied in between bus 2 and 3. The responses for different cases are shown in Figure 10 to 12.

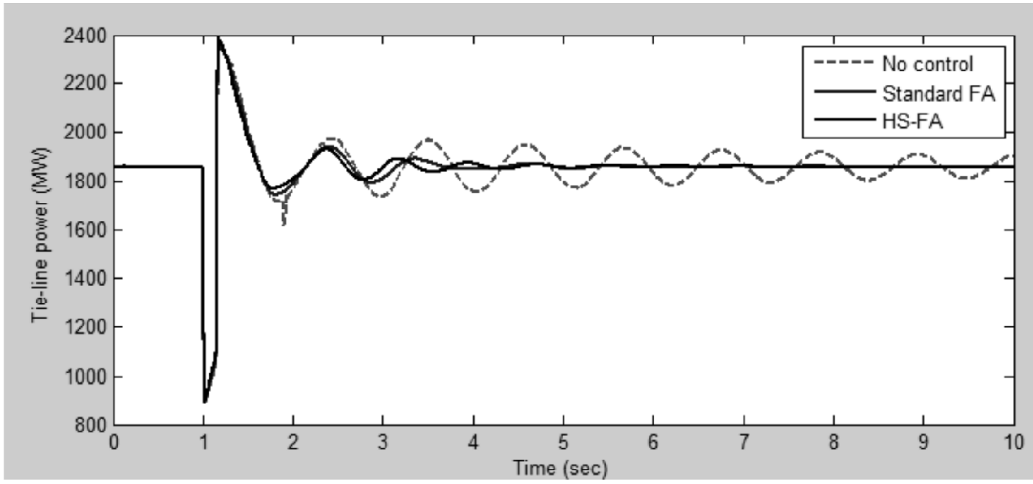

Figure 10: Tie line power for two phase fault

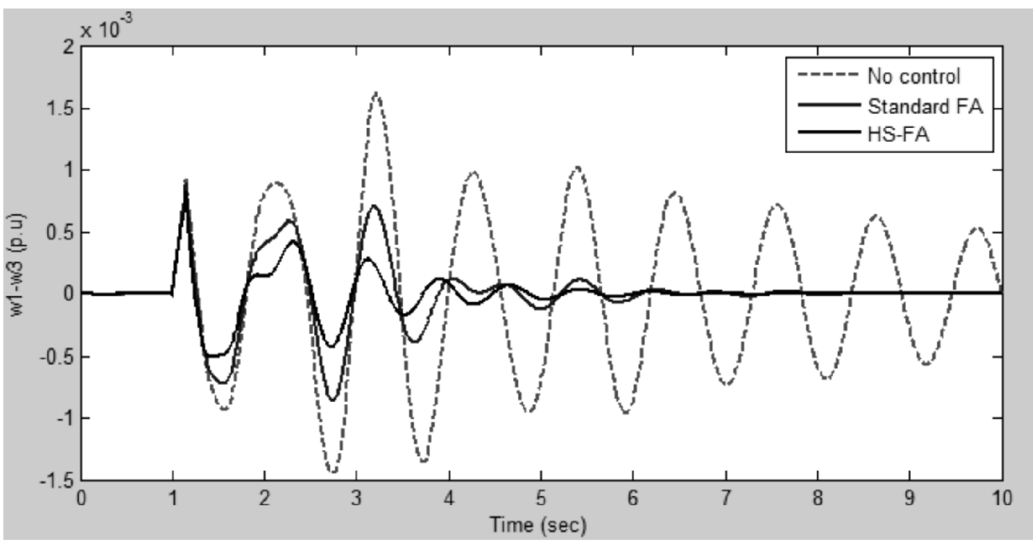

Figure 11: Inter area mode of oscillation for two phase fault

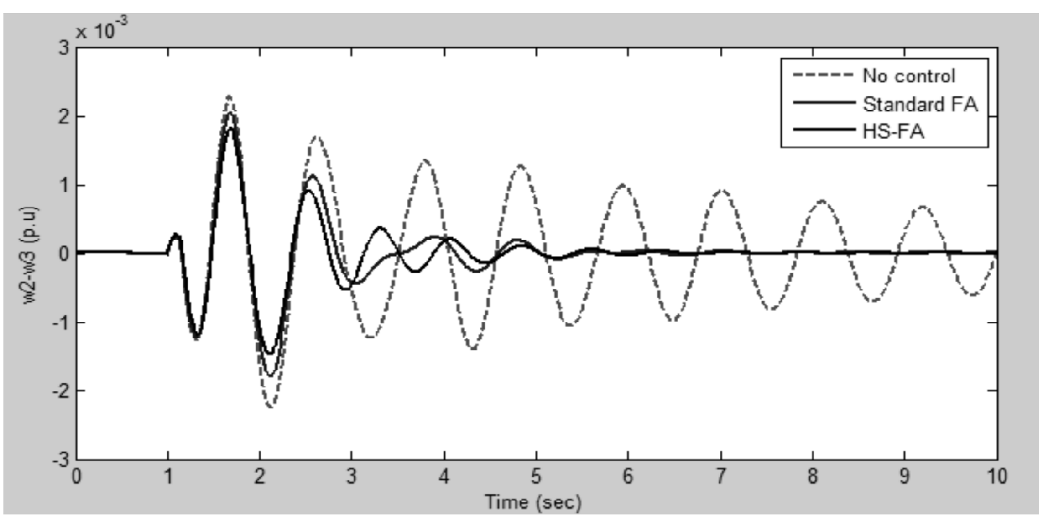

Figure 12: Local mode of oscillation for two phase fault

V. CONCLUSIONS

The simulation results show that the tie line power flow of the three machine system under fault condition is improved. Also the inter area and the local mode of oscillations settles and damp out quickly. Hence this paper concludes that the performance of the hybrid firefly algorithm is better in compare to the standard firefly algorithm in terms of maximum overshoot as well as settling time. The controller is robust and efficient as it works satisfactorily under different fault conditions.

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