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Performance Comparison of IPFC- Based Controllers for to Dampen Oscillations in the Power system

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ABSTRACT

This paper introduces a new approach the nonlinear dynamic model of an SMIB power system incorporated with an interline power flow controller (IPFC) to improve the damping oscillations of a power system. The performance of the IPFC was tested with a PSOMSF DC voltage regulator, compared with the genetic algorithm-based POD (GAPOD) and genetic algorithm-based DC (GADC) voltage regulator under various operating conditions. Time-domain simulation analysis revealed that the newly developed GA-POD and GA-DC voltage regulator has good capability for dampening low-frequency oscillations in power systems.

Key words : Interline power flow controller (IPFC), particle swarm optimization-based multistage fuzzy DC voltage regulator (PSOMSF DC voltage regulator), genetic algorithm-based POD and DC voltage regulator (GAPOD and GADC voltage controller).

1. INTRODUCTION

FACTS devices, such as SVC, STATCOM, UPFC, and IPFC, can be utilized for damping of low-frequency (LFO) oscillations in the power systems. SF Kodad, Anubhaprajapati and Kanchan Chaturrvedi etc all. used a UPFC supplementary controller to dampen low-frequency oscillations [1] – [15]. The IPFC is a completely new FACTS device that adds supplementary controllers, giving it the distinctive ability of damping low-frequency oscillations. In 2011, genetic algorithms were considered by S.F.Kodad, B.V. Sankar Ram, etc all to regulate DC link voltages [16]-[32].

Being universal search techniques, genetic algorithms can help solve optimization problems by utilizing the method of natural selection and genetics. Jitendra Veeramalla and Sreerama Kumar R. proposed a GA-based lead-lag supplementary damping controller and used an SMIB power system to investigate the efficacy of the IPFC [7]. In 2008, the linearized Phillips–Heffron model of power system and damping oscillations studied at the nominal operating point was recommended by Alivelu M. Parimi [8]. In 2011, the PSO technique was employed by N. Rezaei, A. Safari, and H.A. Shayanfar to examine the damping control function of IPFC in an SMIB power system, and the performance index, based on the system dynamics, was utilized as a function to evaluate the potential of different IPFC control signals on the different operating situations of the power system [9]. In 2016, S.N. Dhurvey et al. put forward a simple method to dampen low-frequency oscillations using a fuzzy logic-based IPFC. To help achieve superior damping performance by choosing selecting efficient control signals, the IPFC performance was demonstrated with PI controllers compared with fuzzy logic-based controllers on a modified Phillips–Heffron power system model [10].

2. MOTIVATION AND RELATED WORK

Fuzzy logic controllers are employed for IPFC generally, for the improved functionality, performance, reliability, adaptability, and robustness they provide. Fuzzy sets are produced using speculative methods. To mitigate these shortcomings, a multistage fuzzy controller with a fuzzy switch for IPFC DC voltage controllers is considered in this paper to help improve the dynamic stability of power systems. Accurately constructing the membership functions is one of the most critical steps toward the design of any successful fuzzy control. But obtaining an appropriate set of membership function is a tedious and time-consuming process. It is because of these reasons that GA is employed – to reduce automatically the fuzzy system effort required to attain optimum tuning of membership functions in the MSF controller. Genetic algorithms engage a heuristic search and optimization technique inspired by natural evolution, favoring attractive features like robustness, simplicity, and so on. Yet, they cannot guarantee that the best solution will be established. Because it can sometimes converge to local, rather than global, optima, a modified GA based on the hill climbing method is proposed in this paper to improve the optimization method in order to assure global optima and to improve the speed of the algorithm's convergence to a large extent

The aim of this paper is to design a PSO-based MSF-DC voltage regulator and a GA-POD and GA-DC voltage regulator for IPFC FACTS devices. The efficacy of the proposed controllers is assessed under different operating conditions.

3. PROPOSED MODEL WITH THE IPFC FACTS DEVICE

Studying Fig. 1, it can be inferred that the current induced during low-frequency oscillations in damper windings is negligible, due to which one can ignore damper windings in system modeling. The d and q armature windings of a synchronous machine should greatly raise natural oscillating frequency; accordingly, their Eigenmodes will not modify the low-frequency oscillations. So algebraic equations are enough to explain them.

However, a differential equation must describe the field winding circuit of the machine considering its low Eigen mode frequency and for the reason that it is connected directly to the excitation system to which the supplementary excitation controller is used. Further, it is crucial to integrate the synchronous machine's torque differential equation in the model.

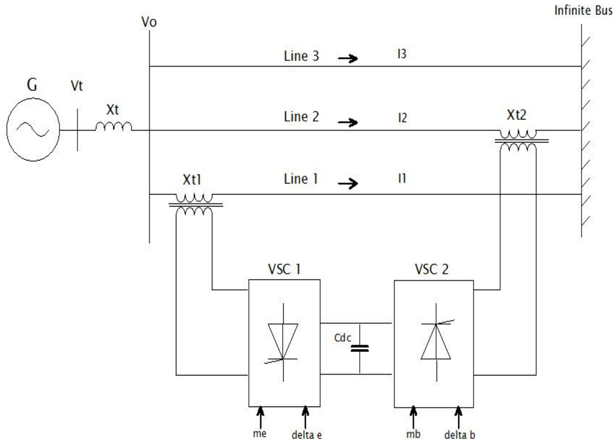

Figure 1: SMIB power system with the IPFC FACTS device

4 . PROPOSED CONTROLLERS

4.1PSO-Supported Fuzzy Damping Controller

The PSO algorithm was presented by Kennedy J and Beernaert R in 2001 [11] and by Dakka Obulesu et al. in 2011 [12–15], which is based on the metaphor of human social interaction. Capable of processing knowledge, this algorithm is based on two component methodologies: artificial life such as bird flocking and fish schooling, and evolutionary computation. PSO The optimization flowchart, as shown in Fig. 2, chooses the fitness function with suitable coding being imperative. In this study, a and b parameters for ΔV_{DC} , $\Delta\left(\Delta V_{DC}\right)$, $\int \Delta V_{DC}$, and output membership functions are expressed in terms of a string that consists of 0 and 1, determined using binary coding. For optimization purposes, the following fitness function is recommended in this work:

$$Fitness = \frac{1}{10 * ITAE}, \qquad IATE = \int_{0}^{t} t\left|\Delta V_{dc}\right| dt$$

The generation number of 5 and population size of 10 are taken to attain an improved carrying into action. Thus, the PSO evolution procedure was applied to the exact time of membership functions of the proposed MSF controller for designing the proposed MSF DC voltage regulator.

4.2 GA-Supported Fuzzy Damping Control

Measuring uncertainties in power system operating conditions is the objective of employing the proposed GAMSF controller. This control strategy consists of a sequence of fuzzy PD and the integral controller having fuzzy switches the fuzzy PD level to rectify fact changes resulting from the corresponding practical constraints and integral stage to reject zero steady-state error.

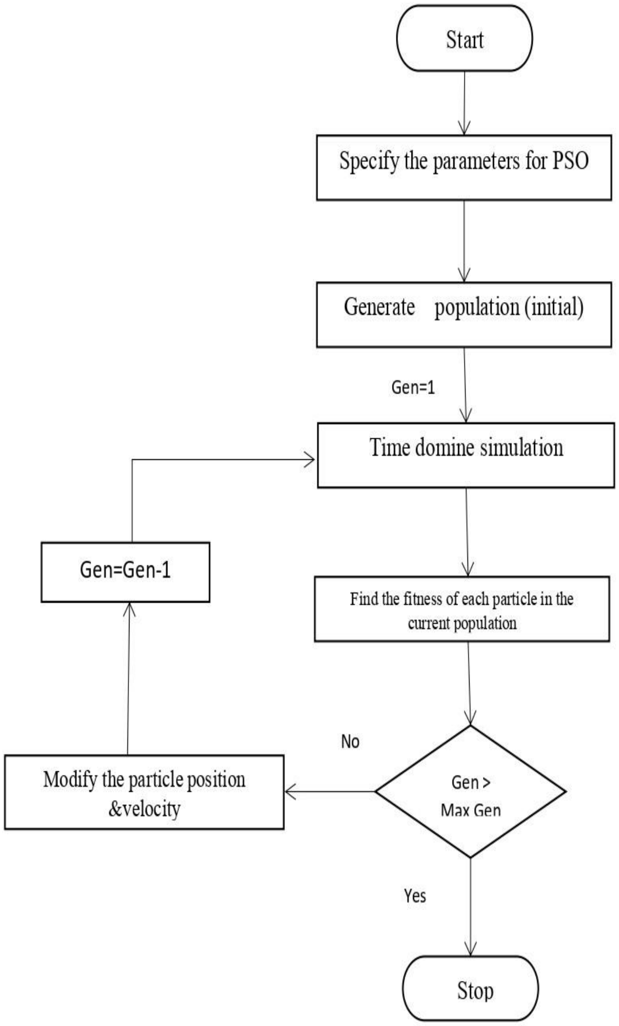

Figure 2: Flowchart of the PSO approach for optimization

To achieve good performance of the fuzzy rule-based control system, it is imperative to design and organize the fuzzy sets carefully.

The complexity of accurate and automatic tuning of the membership functions controls the efficient utilization of this method.

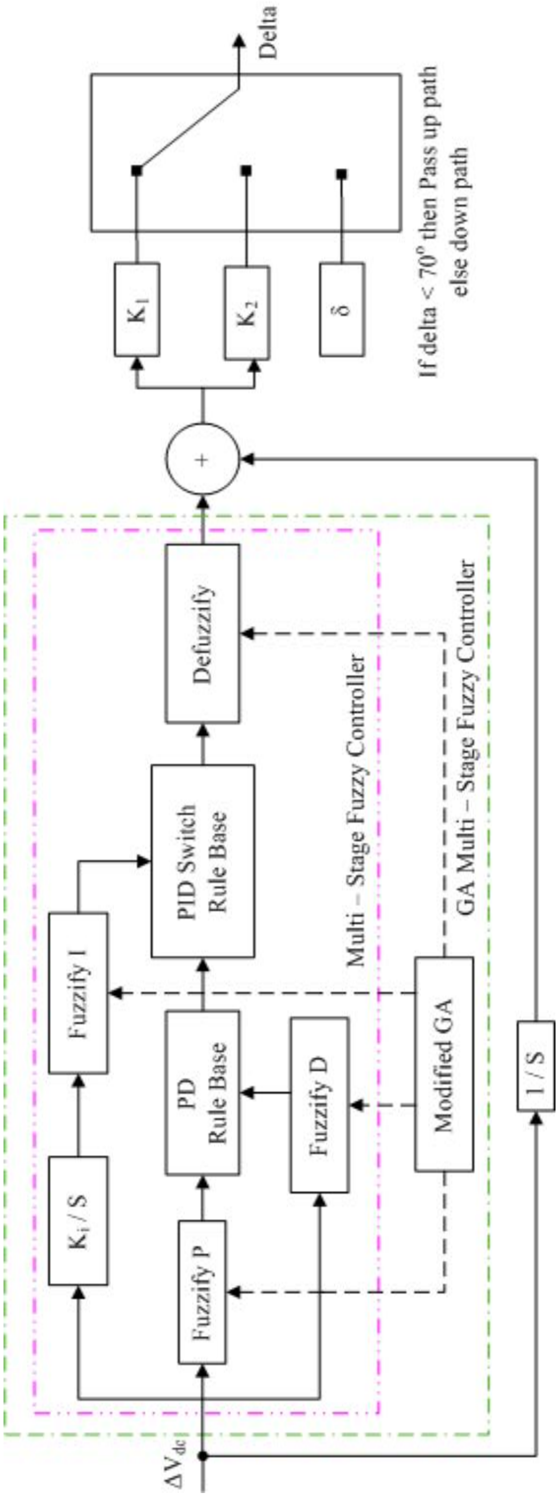

Figure 3:GAMSF DC voltage regulator for the IPFC FACTS device.

This optimization problem is computationally expensive, which renders the extracting of a the suitable set of membership functions tedious, slow, and challenging. GA can address this problem because it is suitable to tackle the dearth of experience or diligence as compared to other methods of searching. The phenomenon, analyzed thus, can be expressed in terms of rules for action and learning processes. The fuzzy system's effort can be reduced by optimally tuning the membership functions in the proposed MSF controller by a new GA based on the hill climbing method. Fig. 3 shows the structure of the proposed strategy for the GAMSF DC voltage regulator

5. SIMULINK MODELS OF POWER SYSTEMS WITH THE PROPOSED CONTROLLERS

Simulating the Phillips–Heffron linearized transfer function model utilizing the MATLAB/Simulink toolbox validated the results obtained in this study.

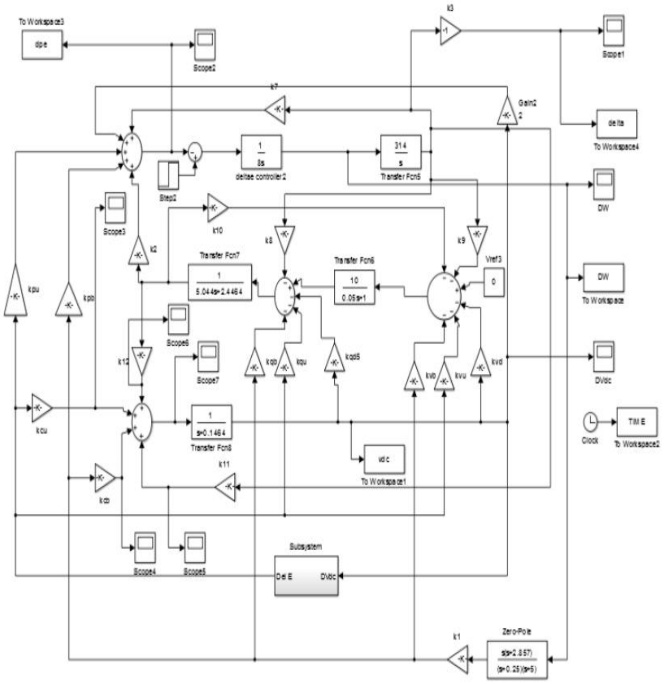

Figure 4:SMIB (three-line) Simulink power system along with the IPFC FACTS device and the MSF DC-voltage controller.

The Simulink models are shown in Fig. 4 and Fig. 5. Fig. 4 shows the Simulink model of the SMIB (three-line) power system, including the IPFC, the damping controller, and the MSF DC voltage controller. Fig. 5 shows the Simulink model of the SMIB (three-line) power system with the IPFC, the POD controller, and the DC voltage regulator.

The Simulink models comprise a mechanical part, typified by an inertia block, and electrical parts, typified by an exciter and generator blocks along with k-constants.

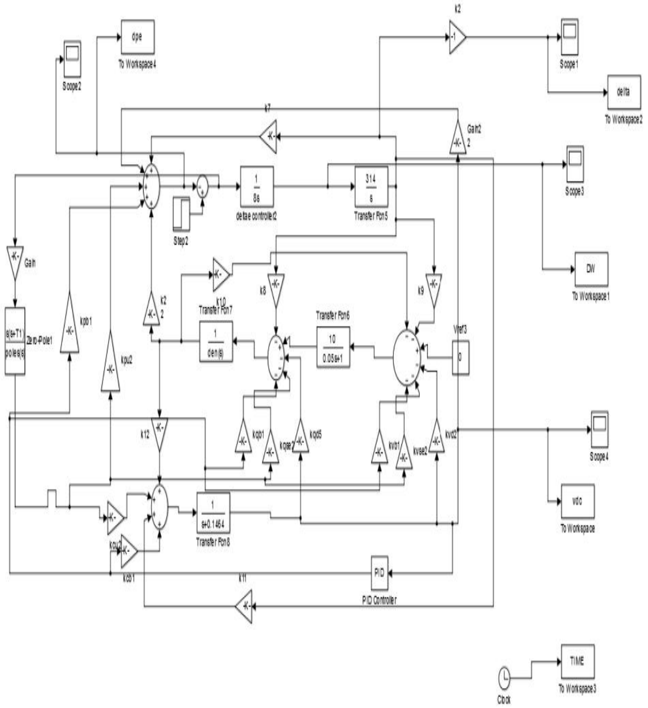

Figure 5: SMIB (three-line) Simulink power system along with the IPFC FACTS device, the POD controller, and the DC voltage controller

6. RESULTS AND DISCUSSIONS

The disturbance is given as a step input; however, the output response is derived from '$\Delta\delta$', '$\Delta\omega$', 'ΔP_e', and 'ΔV_{dc}', denoting the rotor angle deviation, the angular frequency deviation, the deviation in 'P_e', and the deviation in capacitor voltage 'V_{dc}', respectively. Simulink models shown in Fig .4 and Fig. 5 are simulated with a step disturbance of 0.1 pu at low–heavy operating conditions, under the following conditions:

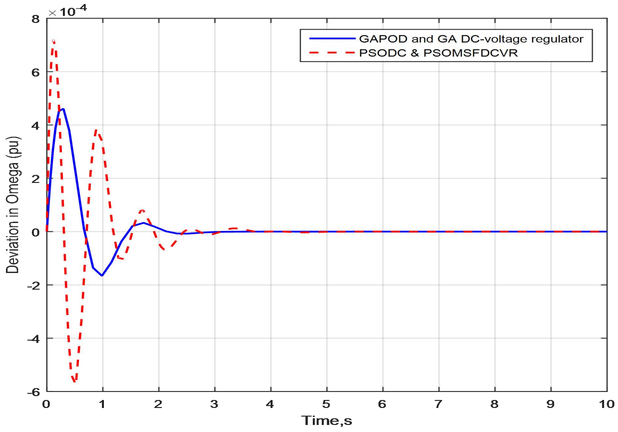

Figure.6: Effect of $\Delta\omega$ with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at nominal load point

Nominal load point: $P_e = 0.8$; $Q_e = 0.15$; $V_t = 1.032$.

Heavy load point: $P_e = 1.15$; $Q_e = 0.3$; $V_t = 1.032$.

The results obtained are shown in Fig. 6 to Fig. 13.

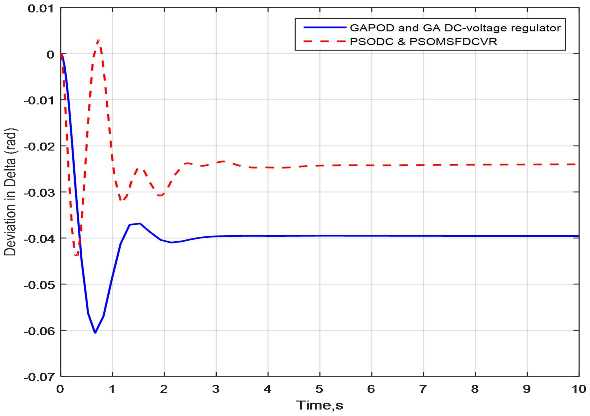

Figure.7: Effect of $\Delta\delta$ with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at nominal load point

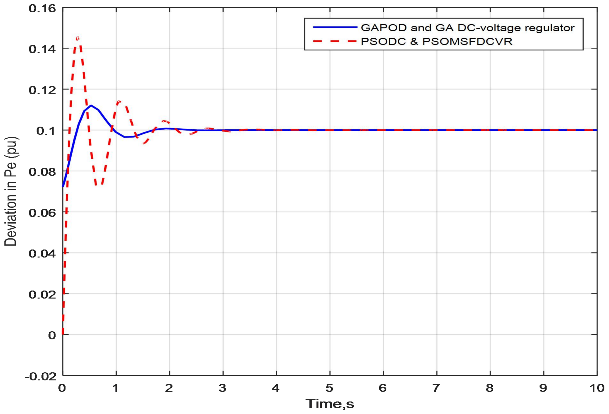

Figure.8: Effect of ΔP_e with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at nominal load point

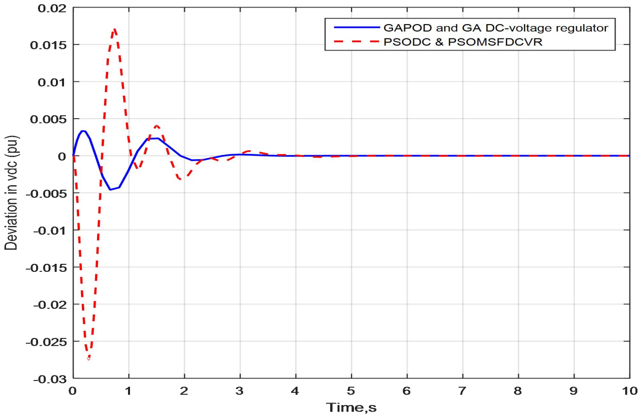

Figure.9: Effect of ΔV_{dc} with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at nominal load point

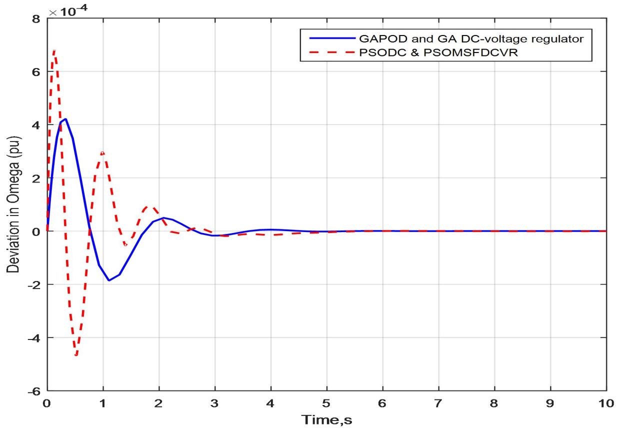

Figure.10: Effect of $\Delta\omega$ with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at heavy load point

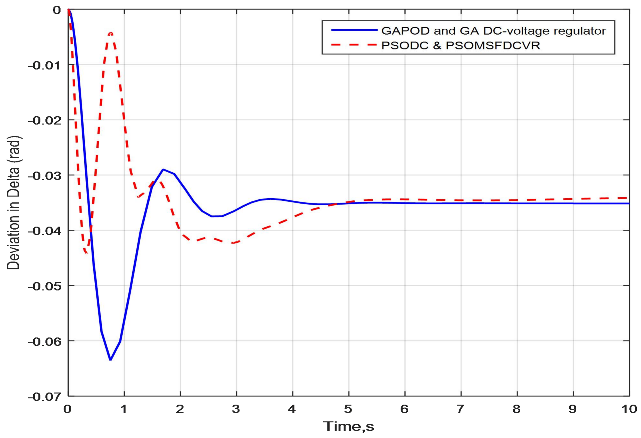

Figure. 11: Effect of $\Delta\delta$ with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at heavy load point

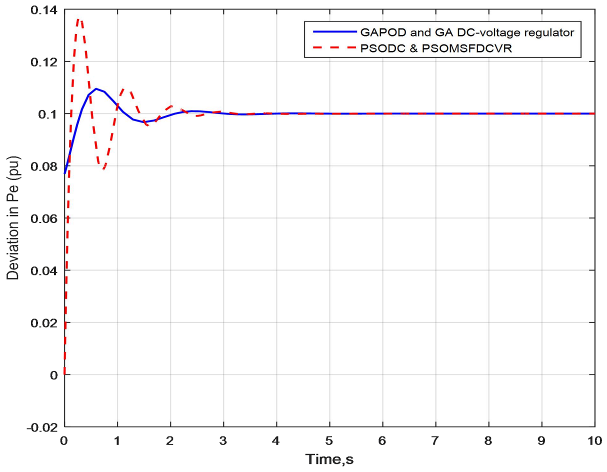

Figure.12: Effect of ΔP_e with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at heavy load point

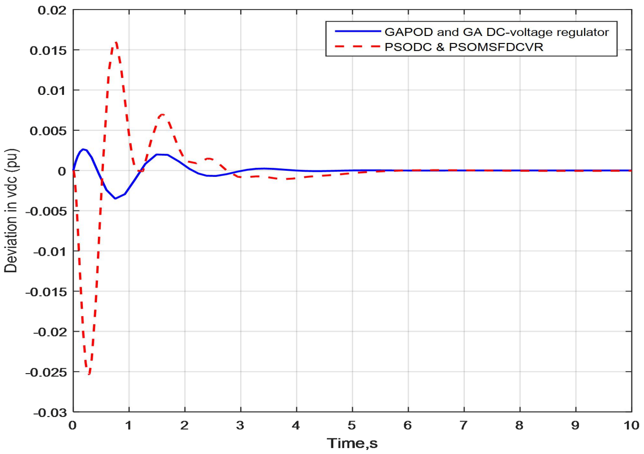

Figure. .13: Effect of ΔV_{dc} with the GAPOD and GADC voltage controller and the PSOMSF DC voltage controller at heavy load point

7. CONCLUSION

This work examined the performance of the IPFC-based damping controllers in damping low-frequency oscillations. It simulated the power system with an IPFC-based PSOMSF DC voltage controller and compared it with the GAPOD and GADC voltage controller under various operating conditions. The GAPOD and GADC voltage controller validates robust performance under different operating conditions.

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